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An embankment is incessantly exposed to the pressure of external forces and to the weathering forces of nature. The resulting impact is changes to the embankment or seawall, such as surface cracks, soil erosion, etc., that are positive indicators of the wasting away of these structures. An experiment was undertaken to determine the feasibility of using a wasting index showing the degrees of wasting or the extent of breakdwons of embankments or seawalls as a checklist of these deteriorations. This report discusses the relationships between the various wasting indicators that appear on the surface over

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of embankments and seawalls, and the countermeasure proposals on combating embankment and seawall breakdowns. Several proposals on designing and constructing embankments and seawalls are also discussed in this report.

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APPARENT WASTING INDEX OF EMBANKMENTS

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Summary

From the very moment of its construction, an embankment (or a sea wall) is incessantly exposed to the pressure of external forces, such as the action of waves, traffic loads that travel over its crown, etc., and to the weathering forces of nature, such as the sinking of foundations, ground compaction, etc. The resulting impact of the above is the appearance of changes to the embankment (or sea wall), changes such as surface cracks, soil erosion, etc., that are positive indicators of the wasting away of these structures. In the course of this study, we undertook an experiment to determine the feasibility of using the wasting index which shows the degrees of wasting or the extent of breakdowns of embankments or sea walls as a check list of these deteriorations. In the report that follows, there is a section devoted to a discussion on the relationships between the various wasting indicators that appear on the surface of embankments and sea walls, and a section that discusses our countermeasure proposals on combatting embankment and sea wall breakdowns. Several of our proposals on how to design and construct embankments and sea walls are also covered in this report.

I. Preface

The total length of our country coastline (excluding Okinawa coastline of about 1,200 km) is about 27,900 km. It has been estimated that of this coastline, approximately 13,800 kilometers can be regarded as "the designated coastline requiring shore-protective structures" to cope with the tidal waves, strong windstorms, high lashing tides, etc., of seasonal typhoons and severe winter weather. So far, however, the construction of these structures has been completed on only about 7,300 km of this coastline; they include about 2,500 km of embankments and about 4,400 km of sea walls. The general coastal construction policy that was followed in the past called for the construction of breakwaters, off-shore dikes, etc., as additional anti-erosion measures after the completion of embankments or sea walls. Needless to say, embankments and sea walls are the main shore-protective structures of our coastline.

It would be difficult to predict the type of shore-protective structure that will be chosen in the future for the aforementioned "designated coastline," but whatever the choice, the undertaking is sure to be an expensive one. Even the choice of an embankment will come to about 1,300 billion yen since the construction cost per

meter of embankment is about 200,000 yen. Required future investments in this field, moreover, are not confined to new construction alone; there will be the need to repair existing embankments and sea walls. The required outlay for this repair work, based on the same unit cost mentioned above (i.e., 200,000 yen per meter), will be about 1,460 billion yen. It can be assumed too that future developments, such as the demand for the conversion of a coastline into a recreation zone, the gradual encroachment toward the shore by urban communities now located to the rear of the beach, etc., will give rise to the need to construct additional protective facilities, such as off-shore levees, man-made beaches, etc. This will mean, of course, more required financial outlays in this field.

It can be said that the need for a sizeable budgetary allocation to construct coastal structures to meet the public demands for more and better services [better usage of coastal areas?] and the shift in government objectives [not further explained] is destined to come about in the not too distant future. This development is sure to be accompanied by a strong demand for a sound, suitable, and timely construction program. To meet this demand, there will develop the need too to review and resolve many pending problems, problems such as the scale of the structures to be built to protect the rear property, the durability of the structures to be built, the maintenance and control of structures, the standardization of structural designs, etc.

Of the many problems mentioned above, the problem of maintenance and control of structures can be regarded as one of the most important ones. Needless to say, rigid maintenance and control not only mean protection of embankment and sea wall capabilities but of their service life as well. Regretfully, however, such has not been the case so far. This shortcoming, one can conjecture, could be contributing to the excessive damages and wear and tear of the existing facilities. Some of the major causes for this lack of proper maintenance and control are: (1) the setting in of a lax attitude toward maintenance and control due largely to inadequate appreciation of the import of this vigilance which means preservation of the structure's capabilities -- that is to say, inadequate recognition of the importance of maintenance and control; (2) the lack of sufficient funds and personnel to permit effective maintenance and control of coastal structures; (3) the absence of clear-cut maintenance and control standards (this absence has hampered the drafting of required budget estimates for this field); and (4) the failure in many instances to draft and incorporate the proper structural maintenance and control procedure to be followed in the designing and

and construction plan that had been drafted for a structure.

The establishment of an effective maintenance and control system of structures requires close coordination of the decisions made by the government on budget allocation and personnel allotment and the technical requirements imposed by the technical standards that had been followed in the designing and construction of structures and in the drafting of the maintenance and control system. With this in mind, we undertook the survey of our coastal embankments and sea walls over a two-year period (1970 and 1971). One of the objectives of this survey was to establish a technical standard for the maintenance and control of coastal embankments and sea walls; another was to carefully observe and index the visible changes and signs, such as cracks, soil erosion, etc., that had taken place to the embankments and sea walls since their construction to estimate the extent of their breakdowns (estimate to determine the required repair or reenforcement work).

The changes and signs noted on the surface of embankments and sea walls generated a number of questions in our minds -- questions such as, "Would it be possible to estimate the structural wasting from these changes and signs?" "What is the real significance of these changes and signs?" "What impact do these changes and signs have on the dynamics of soil composition? on structural dynamics? on hydrography?" "Are these changes and signs really connected to the wasting of structures?" These are interesting questions that merit careful investigation, but in this study undertaken, the focus was placed on the examination of the breakdowns to define the wasting of embankments and sea walls and then on the drafting of a wasting index based on the on-the-spot observation of the visible changes (and signs) that had developed on the surface of embankments and sea walls after their construction.

The wasting index that was developed from the approach mentioned above was subsequently tested as a reference aid in determining the breakdowns of structures. It is believed that the various wasting indices to be developed in the future will be closely coordinated with one another; a section devoted to a discussion on the interrelationship of these indices, however, has been incorporated in this report.

II. Wasting of Coastal Embankments

We would like to first define the expression, "wasting of coastal embankments (kaigan teibo no rekka)," so that its usage in the discussions to follow will be clearly understood.

First of all, an explanation is in order as to why this infrequently used expression was employed in this report. The sentence, "Coastal embankments and sea walls have grown old and useless (kaigan teibo aruiwa gogan ga rokyuka shita)...", is a common remark that one hears frequently. As defined in Kojien [presumably a name or title of a common term dictionary], the word, "rokyu," used in the above sentence means "to age and crumble into decay or to become old and useless" and the addition of the suffix "ka" to this compound characters to read "rokyuka" will make it mean "to become useless with the passage of months and years." We conducted a number of on-the-spot investigations of the various structures to determine the propriety of the remark, "Growing uselessness of the coastal embankments and sea walls with the passage of months and years (kaigan teibo-gogan no rokyuka)," and learned that the inference, "...with the passage of months and years," does not necessarily apply in every case. That is to say, there are embankments and sea walls that show little or no change or deterioration even after months and years of existence and there are those that begin to show radical changes and deteriorations soon after their construction, proving that in most instances, the passage of time has little to do with the intensity and frequency of actions of the external forces and the environmental conditions which are the primary causes of structural deteriorations. The implication, "to become useless," in the above definition is another matter that deserves careful analysis. The question that can be asked is; "How and for what?" Needless to say, the uselessness of an embankment or a sea wall can come about (1) from structural changes and deteriorations that destroy its effectiveness as a protective structure, or (2) from the growth and expansion toward the beach by an urban community to the rear, leading to a situation where the original designed capacity of a structure becomes grossly inadequate to provide the required protection of the changing scene. It should be noted too that the use of the term, "rokyuka," could lead to legal hassle with an insurance firm in a litigation to collect disaster damages. A claim for disaster damages that occur to structures that had weathered the pressure of external forces for months and years would not be contested, but it can be expected that the loophole of charging negligence in the maintenance and control of structures that the term, "rokyuka," can provide will be fully exploited by the insurance firm for any claim made on disaster damages sustained by structures that begin to show wear and tear soon after their construction.

To be sure, this report could have been written employing "rokyuka" with its wide interpretation as the key term, but this

approach was abandoned to avoid the misinterpretations discussed above. The decision was made to define and use the term, "rekka" [TN: literal meaning of this term is "to become inferior/worse"; rendered as "wasting" or "wasted" in this translation per choice made by the authors of this article in their English synopsis attached to the document] in this report.

First of all, it should be noted that even this term is not foolproof. It has been employed for cases where the wasting developed from poor maintenance and control of structures and for cases where the wasting was the result of damages sustained from unusually high wave actions that were not contemplated when the designing work was undertaken.

Provided below is a discussion on the so-called wasting of/wasted embankments and sea walls.

For those embankments and sea walls that had been constructd with the required capabilities and structural facilities in accordance with the technical standards of the period to meet the public demands of the time, the wasting can be grouped, it is believed, into two major categories as described below.

A. Cases where the structural capabilities are no longer able to meet the changing demands of the surrounding areas; for examples, structures that cannot provide the required protection for a rear area that had expanded rapidly and grown in size; structures that have been found to be improperly constructed through research and investigation conducted via advanced technique; obsolete structures requiring reconstruction and renovation to provide the required protection for new buildings and facilities that have been built or are being built in the adjacent areas, etc.

B. Cases where the structures had become unstable and had lost their capabilities to provide the required protection or where there exist some doubt on the performance capabilities of structures and their capabilities to provide the required protection; for examples, structures that developed excessive sinking; structures that begin to show wide surface abrasion; structures that develop surface cracks, surface and crown exposures, etc; structures showing soil erosion, etc.

In essence, A above refers to cases where the embankments and sea walls had "wasted=become obsolete/out-of-date" their capabilities to safeguard the rear area, and B above, to cases where the physical features of embankments had become "wasted (=deteriorated)".

The so-called wasting [deterioration] of embankments and sea walls can be categorized into the following two breakdowns:

1. The loss of original capabilities due to the changes that occurred to the surrounding areas or to the structure itself. Indicators of this wasting are: excessive sinking of the whole foundation, increase in the amounts of high attacking and overtopping waves, emergence of newly constructed buildings in the adjacent areas, coastal erosion and the resultant intensity of high attacking waves, etc.

2. The loss of dynamic stability due to structural changes, partial structural breakdown, and deterioration of materials to indicate that the whole structure is in the process of breaking down. Indicators of this wasting are: face spread abrasion, dispersion of beddings, crown crackings, ground splits, soil erosion, etc. (The development exposing the face spread reinforced concrete via water/wave action is another form of wasting under this category.)

The above categorization can be prepared for A above; no attempt, however, was made for this report.

Generally speaking, the repair or conservation work that had been carried out for embankments and sea walls in the past has been prompted by a combination of the reasons described in A and B above. If the need for a repair or conservation work on embankments and sea walls as indicated by wasting could somehow be represented quantitatively, what great contribution this would be, not only in safeguarding our national property and the life, property, and security of the people living to the rear of the beaches, but in pointing out the way for our government to undertake the required repair and conservation work. In the case of A, a quantitative indicator will be of little service since the basic problem is revolved around the issue of replenishing the wasted [inadequate] protection capabilities, requiring government decisions on major matters such as investments, standards of the [protection] services to be provided, etc. In the case of B, however, the availability of the aforementioned indicator could be a big help, inasmuch as the basic problem is revolved around technical matters. That is to say, as long as the shore protective capabilities of embankments and sea walls are known (such as a certain degree of overtopping waves will occur for a certain meter high heavy sea wall, etc.), the problems under B could be resolved smoothly via technical approach. Moreover, with this indicator, it would be possible to set up a routine repair and renovation work of the strucures to nip the occurrence of major damages.

III. Wasting of Coastal Embankments and Wasting Indicators

A study of the wasting of coastal embankments by focussing one's attention on the structures will show that in the final analysis, this wasting is no more than a breakdown process of structures. In any study to be undertaken in this field, however, it is well to remember that the designing and construction of these old embankments were based on certain set construction standards of the period and that at the time of their completion, they represented the best of their kind available for the period. The breakdown of embankment structures occurs in the form of structural changes, changes that are brought about by external causes, such as the action of waves, overtopping waves, excessive structural weight that sinks the foundation, heavy traffic loads that travel over the crown, etc., and by internal causes, such as the compaction of the core's earth and sand, etc. A careful study of the wasting of embankments and sea walls with the focus of attention centered on the aforementioned external causes, the main catalysts of structural breakdowns, is a prerequisite, it is believed, in coming up with a solution to arrest the wasting of structures during the initial breakdown process. The main discussions of this report, prompted by the above reason, were thus focussed (1) on the calamities that can occur to embankments and sea walls as well as their causes with citing of actual cases, such as the Ise Wan typhoon, and (2) on the breakdown process of structures and the main indicators of the structural wasting in this process. In addition to the above, this report will discuss, with due emphasis placed on the aforementioned indicators, the visible changes (signs) that have occurred on embankments and sea walls since their construction, changes (signs) that could be the wasting indicators of these structures. These changes (signs), it might be added, were employed as the "check-list" in the on-the-spot investigations that were undertaken to determine the present wasting conditions of embankments and sea walls.

A. Causes of Damages to Coastal Embankments and Sea walls

The embankment damages from the typhoon that hit Ise Wan were caused, it is believed, by the excessive high tides and wave uprush that washed away the top of embankments, undermined the foundations of sea walls, and tore down the face armors and wave deflectors(1)(2).

(1) Tsuruta; Aita: Structural Damages Caused by Ise Wan Typhoon and Their Peculiarities, Doboku Gakkai (Institute of Civil Engineering), Speeches at the 7th Coastal Engineering Symposium (1960)
(2) Yoshikawa: Countermeasures Against High Tides at Ise Wan, Doboku Gakkai (Institute of Civil Engineering), 7th Coastal Engineering Symposium (1960)

Based on observations made, the following were determined as the major causes for the extensive damages suffered:

1. Inadequate embankment height and inadequate width of the crown; inadequate barrier provided against overtopping waves and poor resistance to wave actions.

2. Failure to provide adequate armors for the crown and rear embankment spreads; overtopping waves and wave splashes washed away the earth and sand of embankment cores.

3. Too extremely protruded and indented embankment contours; protruding embankments subjected to excessive wave actions and overly indented embankments, to high wave actions to cause excessive overtopping of waves to weaken and destroy the embankment.

4. Improper watertightness of face spread armors; blistering after years of exposure led to seepage and in turn, to the removal of rear earth and sand and eventually to the cracking and destruction of the concrete to destroy the embankment.

5. Weakness of face spread armors; inadequate thickness of the face concrete armors permitted penetration of seeping water from wave actions into the armors to bring about the collapse of the whole embankment.

6. Poor compaction of embankment core's earth and sand; the settling of embankment core accompanied by gaps and hollow spots to permit water seepage from wave actions to gradually destroy the armors and then the embankment core itself.

7. The effect of connecting the concrete wave deflector to the top of the rock armor sea wall; weak connecting joints plus constant exposure to strong action of waves frequently led to the toppling of the deflector to invite greater disaster.

8. The effect of excessive thickness and weight of wave deflector as compared to the lower portion of the face spread; excessive weight of the wave deflector prevented coordinated resistance against overtopping waves, leading to cracks between the face spread armors and eventually to the destruction of the embankment.

9. Sluice gates, conduits, etc., that are the structural weak links of the coastal embankments.

Various measures have been instituted to correct the shortcomings discussued above. New technical methods developed from the lessons learned from the above experience are now being employed in the construction of new embankments.

Most of the damages suffered from high tides in the past were the result of 1 above. To cope with this situation, agencies such

as the Port and Harbor Bureau, Port and Harbor Technical Institute, etc., are now conducting discussions and meetings to come up with a formula(3) to compute the required height of an embankment crown and a method to correct the inadequate heightof the existing embankments. The minimum width of a crown has been set at 3 m(4).

The shortcomings described under 2 above abetted by the inadequate embankment height referred in 1 above were the main contributing causes for the severe damages suffered by the coastal areas of Ise Wan. The bitter lesson learned from this disaster paved the way for the decision to provide block, concrete, or asphalt armor for crowns and rear spreads. This has reduced greatly the occurrence of this kind of disaster. This threat, however, still exists in localities where the terrain hampers the construction of a firm foundation or the smooth undertaking of construction work. This stems from the fact that normally there occurs uneven settling of the foundation to breach the adhesion between the embankment and the face and rear spread armors to develop air gaps and holes; this, in turn, leads to seepage from overtopping waves to endanger the whole structure.

With regard to 3 above, measures are being instituted to correct the contour line of embankments to eliminate extreme protrusions and indentations; where this action is not possible, measures such as the construction of structures to dissipate the waves, etc., are being undertaken.

For 4 above, measures such as the insertion of still-water plates at the joints, conversion to a "maki" /rolled?/ concrete to strengthen the foundation, installation of sheet piles (steel or concrete) in the foundation, etc., are being instituted to ensure the water-tightness of the face armors; other moves that are being carried out to cope with the problems in this field include the construction of riprap to the front to prevent the erosion of earth and sand fill from the wave action and the extension of the "tosui" /literal rendition: transparent water/ channel to prevent water leakage.

(3) Port and Harbor Structures' Designing Standards, by Port & Harbor Bureau, Ministry of Transportation, Japan Port and Harbor Association, October 1969
(4) Standards for the Construction of Safe and Secure Coastal Facilities, by Ministries of Transportation, Construction, and Agriculture and Forestry, December 1967

There were a number of other major typhoons beside the Ise Wan typhoon that hit our coast to cause severe damages to the structures as a result of the shortcomings mentioned in 5 above. The damages suffered from these calamities were traced to the exposed rock piles and thin concrete spreads of face armors. Most of the newly constructed embankments are now being provided with face spread armors of 50 cm thickness or more, and thus, it can be said that part of the past damage causes has been removed. It must be noted, however, that the location and configuration of embankments are the final determinants for the type of wave actions to be encountered by the embankment structures, but sad to say, an embankment with the proper design to cope with this situation has not been developed so far and remains a priority project that requires urgent attention.

With regard to 6 above, it is quite possible to construct embankments that are not only solid but free from the worry of sinking foundation, soil erosion from wave wash, open joints and weep holes that can breach the embankment from armors, damaging uprushing and overtopping waves, etc. This can be done by carefully mixing the embankment's earth and sand with loam or clay. Dictated by the pressure exerted to complete the construction as quickly as possible, this approach has not gained the popularity among the builders as it rightly should. Instead, methods such as the use of sand pumps to blow the sand into place to build medium-packed embankments remain the main embankment construction methods so far to show that very little advancement has been made to correct the shortcomings under this category. In the areas where the terrain and soil prevent the construction of firm foundations,however, new modern methods, such as sand-drain method, vibro-flotation method, etc., have been adopted to carry out the construction work.

With regard to 7 above, measures such as the laying of pell-mell concretes in front of the rock piles, construction of rock pile embankments with tie-backs to "deadmen" buried in the earth, etc., are being instituted in the areas where severe hits from strong wave actions are expected, but so far, none of the expected strikes has happened.

Measures carried out under 7 discussed above are also being instituted for the shortcomings under 8.

With regard to 9 above, measures are being undertaken to strengthen the positions where sluice gates, conduits, etc., are installed

so that they will not develop into the weak links of the structures and also to see that their connections to the embankment structures (both front and back) could be carried out easily and smoothly. Because of the failure to carry out comparable strengthening of the adjacent areas, problems such as the sinking of the adjacent areas, cracking of joints, etc., have been surfacing to become new critical problems in this field.

In recent years, the following have developed into major problems of embankment destruction.

10. The wear and tear of the edges of spreads, triggering the gradual breakdown process and the eventual collapse of the foundation.

11. The destruction of the crown by the heavy vehicle traffic followed by the sinking of the embankment earth and sand and the exposure of the bedding anchor due partly to the poor resistance capabilities of the rear spread and the bedding anchor to create a situation where the whole structure could suffer severe damages from heavy storm or overtopping waves.

The development of 10 above came about, it is believed, as a result of (1) the failure to strengthen the lower portion of the embankment at the same time the upper portion was strengthened as a preventive measure to cope with high tides accompanying strong typhoons, such as the Ise Wan typhoon, that can cause extensive damage; (2) the erosion of the coastal areas which is developing into a serious problem; and (3) the greater exposure of the edges of spreads to the action of waves brought about by the filling of offshore water to build sea walls instead of embankments.

In the past, the embankments constructed along the coastline with fairly well developed front beaches were provided with relatively shallow beddings. The work of solidifying these beddings, moreover, was cut to the minimum or was undertaken to meet the minimum requirements only. Thus, the erosion of the front beaches that normally occurs with the seasonal beach line changes led to the greater exposure of the edges of the embankment spreads to wave wash action of the coastal waves to accentuate their wear and tear and subsequently to the shifting and sinking of foundations and to the drainage of embankment earth and sand from the bottom to gradually break down and destroy the whole embankment. For the embankments that were expected to face heavy action of the waves and for the sea walls that were constructed on reclaimed land to the front, the beddings of their foundations were made deeper and steel

or concrete sheet piles were installed in the lower section of the foundations to serve as countermeasures against the aforementioned wear and tear and drainage. In many areas too, measures such as the building of rip-rap, laying of huge rocks, etc., were instituted to cope with the excessive wear and tear of the spread edges. Despite these efforts, however, very little inroad has been made so far to resolve this problem. The basic difficulty, it should be noted, stems from the fact that the wear and tear of spread edges is a development governed by a number of external factors including the seasonal changes that occur to the front beaches, the environmental changes that take place as a result of undertakings such as reclamation work, construction of port, harbor, and coastal facilities, changes generated by the construction of foundations or by the solidification work undertaken on beddings, etc. The difficulty of conducting visible check of bedding rocks, submerged below the water surface, is another matter that is compounding the problem on hand. At the present time, reliance is being placed on the bedding consolidation work (beddings with shallow foundation but reinforced with short sheet piles) to serve as the main deterrent against the aforementioned wear and tear. One of the criticisms being aired against the above is that sheet piles in the order of 3 to 5 meters that are being employed are too short to be effective, particularly in preventing the erosion of very fine grain soil, and can lead to the development of weep holes and gaps in the embankments.

The development under 11 above was brought about by the more extensive use of the embankments' crowns as roadways to help meet the cargo hauling requirements of our country that have been boomeranging in recent years. The heavy loads and traffic that travel over the crowns have caused heavy damages to these crowns in many areas and have led to the exposure of rear spread armors and bedding anchors to nature and to the erosion of embankment soil and armors. In connection with this problem, it is well to remember that in the past, the designing as well as the construction of an embankment or a sea wall was undertaken with little or no thought given to its use as a roadway to carry heavy loads and traffic. Thus, if there develops a need to do so, due consideration must be given to see that the load that it will be called upon to carry will be well within its capacity and will not lead to its breakdown.

B. Breakdown Process of Coastal Embankments and Visible Indicators of Changes (Wasting Index)

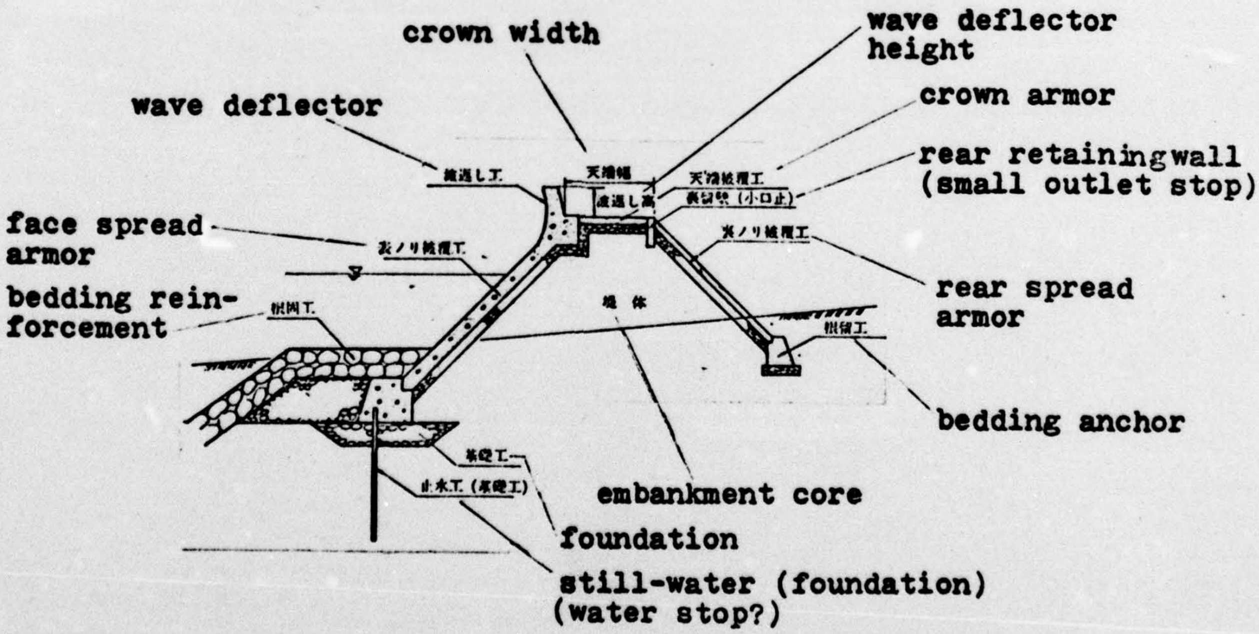
It is believed that the breakdown process of embankments and sea walls that had suffered damages from uncommon weather conditions will generally follow a certain set pattern. This statement does not apply, however, to the breakdown caused by rare typhoons, such as the one that hit Ise Wan (this kind of disaster poses much greater and more complex basic, structural, and planning problems). The research undertaken so far to probe this breakdown process and phenomena has been far from satisfactory. This is especially true for the fields of soil engineering and structural mechanics. The difficulty of conducting structural analysis because of the different and varied mixtures of soil and concrete that are employed in the construction of embankment structures, the problem of accurately determining the precise role played by the various external forces, such as the action of waves, in the breakdown process of structures, the absence of a uniform national construction standards for embankments and sea walls that can serve as the basis for conducting meaningful technical analysis of structures, and the lack of proper maintenance and control of embankments and sea walls as a result of the laxity in vigilance that had set in since the construction (a la the saying, "Disaster comes around just about the time the last one is forgotten") are some of the main negative reasons that have discouraged the undertaking of research in this field. Extensive developmental work, such as the establishment of seaside industrial zones, construction of housings on reclaimed coastal areas, etc., have been taking place along our coastline in recent years; this could mean that a disaster hit of the future will have much greater impact than in the past. In addition to the destruction of life and property of the people living in the area, a disastrous calamity of the future can seriously affect the economy of our whole country. For this reason, there exists the urgent need to push for the research on soil engineering and structural mechanics of coastal embankments.

If it can be assumed that the wasting of an embankment or a sea wall is a breakdown process of its structures, then it can be assumed that the unique visible changes or multiple combination changes (e.g., initial surface cracks, sinking process, etc.) that occur /to the structures/ are manifestation of the various stages of this breakdown process. If one can show the wasting of structures by examining these visible changes, what great contribution it will be not only for the maintenance and control work that must be done but for the designing of structures as well.

The flow charts, 3.2 (1)-(7), were prepared from the visible changes that were observed in the breakdown process of embankments. The information provided (restricted to embankments only) has not been confirmed, but represents the best analysis from available data. A sea wall is generally regarded as an embankment without the rear spread armor and the bedding anchor; thus, the structural data given for the embankments in this section should apply to sea walls as well.

The shape and the nomenclature of a typical embankment are shown in Chart 3.1. The model chosen for this study was a three-sided concrete armor embankment. The thickness of the face spread armor was assumed to be 50 cm, and the thickness of the armors for the crown and the rear spread, 15-20 cm. Actually, there are many different types of embankments in existence; there are some with asphalt as the armors for the crown and the rear spread, some with the face spread standing almost vertical, and some with multiple front and rear spread sections. The one in Chart 3.1 was selected in the belief that it adequately represented the other types and that it will adequately serve the need for the discussions to follow on the visible changes that occur to embankments.

Chart 3.1 - Nomenclature of a Coastal Embankment



1. Hastening of Embankment Disintegration by Erosion of Foundation and Other Causes Brought About by Wave Action (see Chart 3.2 (1))

Breakdown cases that fall under this category are those that occur from the action of waves. The disintegration (scattering) of the reinforced bedding from the pressure exerted by wave forces eventually erodes the foundation; this, in turn, leads to the collapse of the embankment. This breakdown process is shown in Chart 3.2 (1). In most cases, however, the actual breakdown process does not go beyond the disintegration of the reinforced concrete or the erosion of the lower half of the foundation. It can be said too, that there have been very few cases where a complete collapse had occurred from the first exposure of an embankment to some unusual weather condition. Exposure, however, to continuing adverse weather conditions can cause severe damages to the structures to bring about the collapse. There have been many cases where the erosion of an embankment had been triggered by a minor calamity. In most of these cases, the erosion developed small breaches that remained undetected and as a result, subsequent calamities served as the aggravating force for these breaches to bring about embankment rupture and crown cracks. The resultant impact of this development was the seepage of overtopping waves and rain water into the embankment core to shift the earth and sand to break down the solidity of the foundation. This meant, of course, that whenever a new storm hit the area to cause the waves or the rain to overflow the embankment or when the crown was used excessively by heavy traffic, there would be more extensive and more rapid breakdown of the whole embankment. To cope with this situation, steps such as the installation of sheet piles to halt the seepage below the bottom half of the foundation, etc., have been initiated. It has been reported[5], however, that the effectiveness of these steps has been hampered greatly by the failure to correct the construction flaws that still exist in the field, such as the improper tie-ups of the sheet piles, shortness of the sheet piles used, excessive fineness of the sand used for embankment core, etc.

As the erosion of the foundation becomes more pronounced, the foundation begins to sink to develop a breach between the face spread armor and the foundation to open the way for the embankment earth and sand to wash away. When this occurs, small air holes and gaps begin to develop within the embankment. As long as they remain

(5) Four Basic Coastal Problems, by Toshima Osamu, Doboku Gijutsu Shiryo (Civil Engineering Technical Data), 10-5, pp 215

small, no serious problem will develop, but their growth in size could lead to trouble, such as foundation break, cracking of crown, rupture to concrete structures, etc. Concrete embankments have greater resistance to these breakdowns, but once they set in, even these embankments are doomed to destruction. Failure to institute corrective measures to arrest these breakdowns will lead to further disintegrations, such as the cracking of the rear spread armor (and even face spread armor with its thicker covering), sinking of the wave deflector, damage to the crown, etc., and eventually to the collapse of the whole embankment.

In addition to the case mentioned above, the drainage of embankment earth and sand has occurred from cracks and angular breaks that developed at the ground site. The cracks referred above were caused by the sinking or forward tilting of the foundation, and the angular breaks, by the use of poor material, poor construction work, or friction between the bedding anchors that shifted their positions from the action of waves. The primary cause of the aforementioned sinking and tilting could be traced to poor designing work; that is to say, the inadequate designed capacity of the foundation to handle the weight load of the wave deflector and the face spread armor.

The erosion of embankment earth and sand normally develops at a very slow pace beginning with weep holes and small gaps. The difficulty of detecting these flaws has prevented the adoption of effective countermeasures and has led to the development of serious damage to the embankment.

Chart 3.2 (1)

Waves

Scattering of reinforced bedding

Erosion of foundation

Sinking of foundation

Breach between foundation & face spread armor

Erosion of embankment earth & sand

Air holes underneath the face spread armor

Crown crack from soil erosion

Sinking of crown; cracking of rear spread armor; rupture at ground site (enlargement of air holes)

Cracking of face spread armor

Poor designing

Inadequate foundation support capacity for heavy face spread armor & wave deflector

Foundation forward tilting

Slippage of face spread armor

Breach with wave deflector; breach & slippage of face spread

Poor construction work

Angular break at ground site

Erosion of embankment earth & sand from lower part of foundation

Air holes (small) underneath the face spread armor

Cracking of crown

Sinking of crown & breach with wave deflector

Sinking of face spread armor

Development of directional misalignment of wave deflector & embankment site with coastline & coastline angle from slippage, breakdown, & angular break

Rupture of face spread armor

Major sinking of wave deflector

Major sinking of crown

Erosion of embankment earth & sand

collapse of embankment

2. Hastening of Embankment Disintegration by Crashing Waves (see Chart 3.2 (2))

Waves packing powerful force that crash against embankments have been known to tilt the wave reflector backward and in some cases, to topple it completely. There have been a number of cases where waves of this magnitude had destroyed embankments with weep holes below the face spread armor.

It can be expected that strong waves that crash against embankments will bring heavy overtopping waves and that defective crown or rear spread armor will be suffering severe damages from this overtopping. Recent measures instituted to cope with this problem include the construction of wave breakers and the thickening of the face spread armor. This approach eliminated the need to tamper with the idea of building a larger wave deflector and has reduced greatly the damages suffered from the crashing waves.

<u>Chart 3.2 (2)</u>

Crashing Waves

↓

Backward tilting of wave deflector

Toppling of wave deflector
↓
Increase in the amount of overtopping waves
↓
Damage to crown
↓
Damage to rear spread armor
↓
Collapse of embankment

Breach between face spread armor and ground surface
↓
Erosion of embankment earth & sand
↓
Sinking or rupture of face spread armor
↓
Damage to rear spread armor
↓
Collapse of embankment

(Where face spread armor is thin or where air holes exist underneath the face spread armor)

Rupture or damage of face spread armor
↓
Erosion of embankment earth & sand
↓
Collapse of embankment

(continued Chart 3.2 (2))

(Large Amount of Overtopping Waves)

Penetration from cracks or ground sites of crown and rear spread armor or both

↓

Flow from the front of rear spread armor

↓

Erosion of embankment earth & soil

Cracking of crown & rear spread armor ←........(Where air holes exist underneath the crown or rear spread armor)

↓

Damage to crown & rear spread armor

↓

Erosion of embankment earth & sand

↓

Collapse of embankment

3. Hastening of Embankment Disintegration by Water Level Difference Between Inside and Outside the Embankment During High Tides (see Chart 3.2 (3))

Breakdown cases that fall under this category are those that occur from the difference in the water levels within and outside the embankment during high tides. This difference can cause the tilting of the wave deflector (parapet) to develop a small drain passage; this passage gradually grows in size to topple or damage the wave deflector.

Chart 3.2 (3)

Difference in Embankment's Internal and External Water Levels During High Tides

↓

Backward tilting of wave deflector

↓

Breach between face spread armor and ground surface

↓

Outward flow of water from embankment (via weep holes)

↓

Air holes underneath the crown

↓

Crack and rupture of crown

↓

Toppling of wave deflector

↓

Erosion of crown and rear spread armor

↓

Collapse of embankment

5. Hastening of Embankment Disintegration by Heavy Traffic and Loads That Pass Over the Crown (see Chart 3.2 (4))

It is believed that because of natural phenomena, such as the compaction and settlement of embankment earth and sand, gaps and weep holes can be found in all embankments, even in those embankments under the best of control system. It can be said too that it would not be wrong to assume that because of the inevitable embankment soil erosion that occurs from a multitude of causes, weep

holes, normally found under the crown, are common flaws of all embankments. The use of the embankment top by vehicles carrying heavy loads, therefore, could have a serious effect on the crown. It could easily lead to the cracking of the concrete armor of the crown and to the erosion of the soil beneath it to bring about its ultimate destruction. This problem, it may be pointed out, is no different from the one faced in the maintenance of highway pavements. Basically, all embankments were designed and constructed as shore protective structures against the rising water level of the seas and were not conceived to serve as roadways to carry heavy cargoes. Thus, in the designing work undertaken, attention was focussed on the strength of the face spread armor and the foundation to see that they were firmly built and were fully capable of resisting the onslaught of the frontal waves, but little importance was placed on the strength of the rear spread armor or the bedding anchor. For the latter, about the only consideration given was to see that they were strong enough to support the resistance of the embankment against wave forces and hydraulic pressure. Needless to say, the use of these inadequately prepared embankments for the hauling of heavy loads has been taking its toll. The higher earth pressure of the embankment soil, the inability of the small and shallowly implaced bedding anchors to bear the weight pressure, etc., have led to ground rupture, cracking of rear spread armor, exposure of bedding anchor, etc., to change the outer appearance of the embankments. These developments accompanied by the cracking of the crown and the rupture of the ground site have intensified greatly the erosion of embankment earth and sand. The end result of all of the above has been the enlargement of the seepage openings, the hastening of the ultimate destruction of the crown and the rear spread, and the development of a situation where a hit by a calamity packing heavy overtopping waves could mean the end to many embankments.

Chart 3.2 (4)

Heavy Traffic Loads

(Majority with gaps and weep holes beneath the crown)

Cracking and soil erosion of crown

Angle break, slippage, or break at the ground site

Angle break, breach, or slippage of rear spread or wave deflector

Compaction & sinking of embankment earth & sand

(With strong bedding anchor)

Vulnerability of rear spread armor

Slippage, breach of rear spread armor

Erosion of embankment earth and sand

(With weak bedding anchor)

Exposure of bedding anchor

Erosion of embankment earth and sand (from precipitation and overtopping waves)

Sinking of crown
Sinking of rear spread armor
Ground rupture

Rupture of rear spread armor

Outflow of embankment soil due to heavy overtopping waves

Collapse of embankment

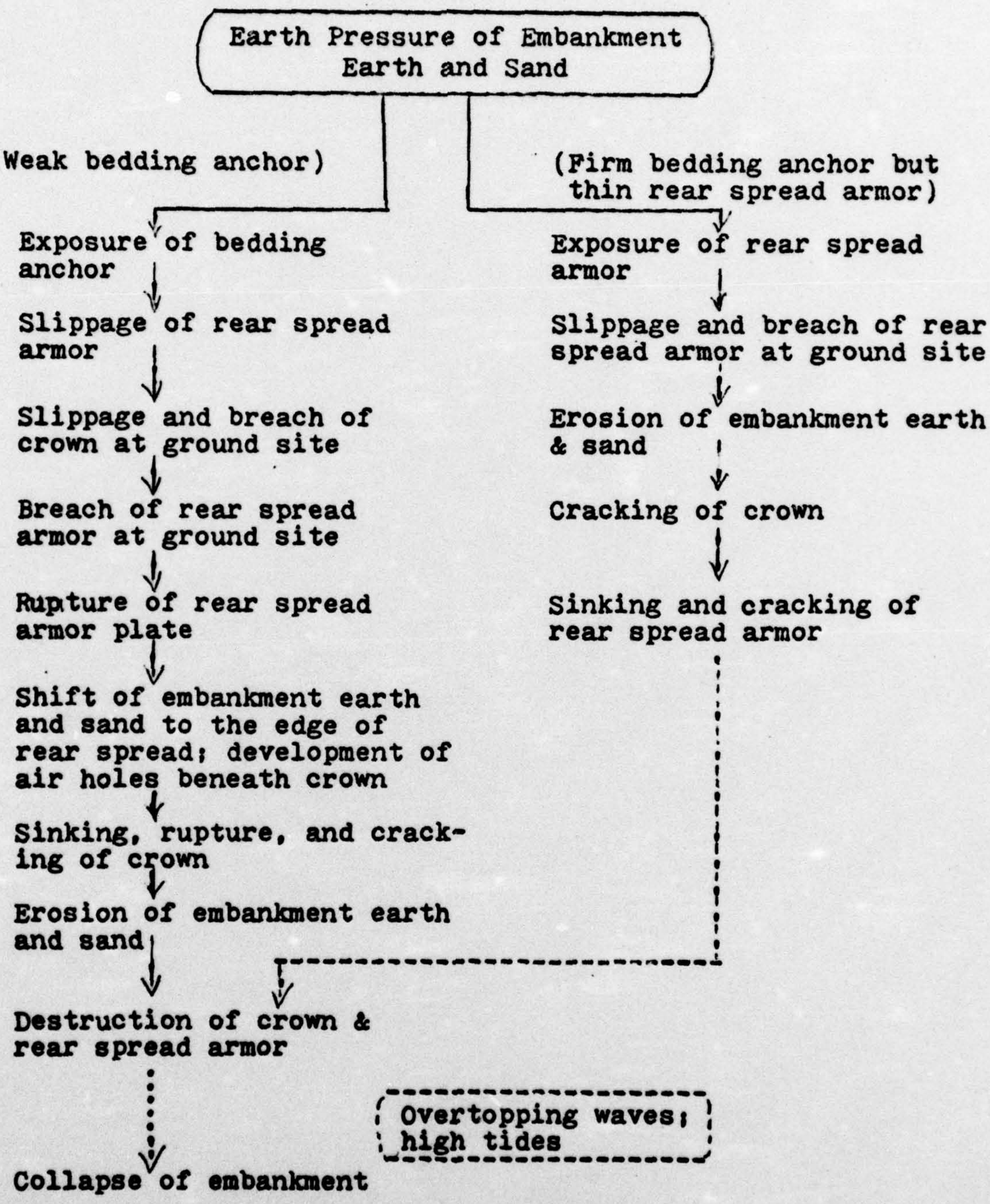
5. Hastening of Embankment Disintegration by Earth Pressure of Embankment Earth and Sand (see Chart 3.2 (5))

The exposure of the bedding anchor and the rear spread armor will develop under the following conditions: (1) the implacement of the bedding anchor is too shallow in relation to the height of the embankment; (2) the bedding anchor is too small to resist the earth pressure of the embankment earth and sand; and (3) the rear spread armor is too thin and weak despite the fact that the bedding anchor had been amply strengthened.

The above plus the inadequate height of the crown prompted the adoption of the measure to pile up the embankment core higher, but even this step will be to no avail against the above development without the reinforcement of the bedding anchor and without the decision to cancel the deepening of the tide stopper located behind the bedding anchor. This kind of breakdown process can occur easily when the rear spread armor is a single section and where there is a big elevation difference between the bedding anchor and the crown. If the elevation difference is 5 m or more, ample reinforcement of the multiple section [of the rear spread armor?] or the bedding anchor must be undertaken.

The drainage of the embankment core, aggravated by heavy overtopping waves, is a distinct possibility under this breakdown process, but for the most part, the normal breakdowns are changes, such as the slippage and breach of the rear spread armor, rupture of the crown at the ground site, breach of the rear spread armor with thin covering, etc., that are all visible from the surface. There have been very few cases where these breakdowns had not been noticed and had been left unattended to bring about the downfall of the whole embankment.

Chart 3.2 (5)


Earth Pressure of Embankment Earth and Sand
(Weak bedding anchor)
(Firm bedding anchor but thin rear spread armor)
Exposure of bedding anchor
Slippage of rear spread armor
Slippage and breach of crown at ground site
Breach of rear spread armor at ground site
Rupture of rear spread armor plate
Shift of embankment earth and sand to the edge of rear spread; development of air holes beneath crown
Sinking, rupture, and cracking of crown
Erosion of embankment earth and sand
Destruction of crown & rear spread armor
Collapse of embankment
Exposure of rear spread armor
Slippage and breach of rear spread armor at ground site
Erosion of embankment earth & sand
Cracking of crown
Sinking and cracking of rear spread armor
Overtopping waves; high tides

6. Hastening of Embankment Disintegration by Compaction and Settlement of Embankment Earth and Sand (see Chart 3.2 (6))

In most cases, embankments are constructed by using the available sand on the front beaches after which the three sides are provided with coverings. The compaction of the sand blown onto the embankment by a side pump is normally confined, however, to the bull-dozers used for leveling. Therefore, after the completion and the passage of several years, gaps normally develop between the concrete blocks that had been laid as coverings on the three sides because of the compaction and settlement of the embankment core. Even if the best of precaution is taken at the time of the construction, moreover, there normally will develop seepage of rain water, etc., into the embankment. The fluctuating level of the tides that hit from the front affects the water level within the embankment, causing the penetration of very fine grain of sand to settle in-between the rocks that had been laid below the coverings. These sand eventually create weep holes and gaps inside the embankment core to cause the sinking and cracking of the concrete blocks of the crown from their own weight, which, in turn, lead to the rupture and soil erosion of the ground site. Needless to say, these breakdowns can be greatly accelerated by the excessive use of the embankment crown by heavy vehicles and loads. Growing deterioration of the crown will be accompanied by growing seepage of rain water, overtopping waves, etc., into the embankment; this, in turn, will aggravate the drainage of the embankment earth and sand from both the front and the back of the embankment. This problem, it should be noted, will be greatly magnified if the embankment core is made up of very fine sand and soil. As can be seen from the above, the structure that encounters the severest of damage from this breakdown is the crown. Fortunately, repair or replacement of the damaged crowns is being carried out because if unattended, grave consequences, such as the exposure of the bedding anchor, breach in the rear spread armor at the ground site, etc., could develop and could bring about the situation where a hit by severe overtopping waves would destroy or wash away the crown and the rear spread armor to topple the whole embankment.

A number of countermeasures, such as the use of more sticky soil for the embankment core to provide better adhesive strength, placement of suitable filter layer in-between the embankment soil and the fill, etc., are available to cope with the breakdowns under this category, but so far, none of these measures has been instituted.

Chart 3.2 (6)

Compaction and Sinking of
Embankment Earth and Sand

Development of weep holes & gaps beneath
the face and rear spread armors and crown

(in the order of cm)

heavy
traffic

Drain of fine earth & sand
into lower section of embank-
ment and filled rip rap

Cracking of crown

Rupture of crown concrete blocks

Slippage & break of work site;
slippage and break of wave de-
flector and rear spread armor
from ground site

Erosion of embankment earth &
sand caused by seepage of over-
topping waves and rain water
from crown (drainage from edge
of rear spread armor)

Exposure of bedding anchor

Slippage and break of rear spread
armor at work site

Rupture of rear spread armor

overtopping
waves

Collapse of embankment

7. Hastening of Embankment Disintegration by the Sinking of Base From the Weight of Embankment (see Chart 3.2 (7))

The breakdown under this category differs from the breakdown caused by the compaction and settlement (sinking) of the embankment earth and sand that was discussed in the previous section. The cases that fall under this category are those that occur from the inability of the base to support the weight of the embankment. This inability usually leads to its sinking and in turn, to the uneven sinking of the various parts of the embankment to develop structural breakdowns, such as rupture of concrete work, exposure of the bedding anchor, breach at the ground site, etc. The deterioration rate of these structures will be accelerated greatly by developments, such as a hit by a heavy storm with strong attacking waves, or by abuses, such as the use of the crown by heavy traffic and loads, to bring about the early collapse of the whole embankment.

Weak bases must be renovated and reinforced to meet the requirements. Due care must be exercised at the time of the designing to see that the base will be strong and firm and that there will be no uneven sinking of the embankment. These precautions will prevent the development of serious problems.

Chart 3.2 (7)

Sinking of Base From the Weight of Embankment

↓

Sinking of foundation of face spread armor comprised of large sections
↓
Forward tilting of wave deflector

Slippage & breach at worksite from uneven sinking
↓
Shifting of embankment earth and sand due to flow of rain water, overtopping waves, etc., into embankment
↓
Cracking of crown and rear spread armor
↓
Erosion of embankment earth & sand
↓
Collapse of embankment

Sinking of bedding anchor
↓
Slippage & breach between rear spread & crown at ground site
↓
Slippage & breach of rear spread & bedding anchor at ground site

C. Visible Indicators of the Wasting of Various Parts of an Embankment

In section B, discussions were conducted on the breakdown process of embankments and on the typical changes that occur to the various parts of an embankment that can be seen from the outside in the breakdown process. In actuality, an embankment is made up of many more sections than those shown in Chart 3.1 and if closer observations are made, many more breakdowns can be detected.

In essence, the actual relationship between the breakdown process and the changes that appear on the surface of an embankment still remains a matter of conjecture. It is believed that a clearer understanding of this relationship could be gained by adopting the following approach to the problem: (1) first catalogue the visible changes that have occurred to the various parts of an embankment (to serve as ready reference aid), and (2) then compare the changes observed in the actual breakdown survey conducted on an embankment with the changes listed in the aforementioned catalogue to obtain corroborative evidence of the relationship between the two. The use of this knowledge and the catalogue mentioned above should permit the gathering of reliable data on the breakdown process (i.e., the extent of the wasting) of embankments.

Most probably, the basic problem to be encountered under this approach will be the difficulty of correctly evaluating the significance of the visible changes to the embankments that had been observed and correctly categorizing them under the proper groupings.

Table 3.1 presents the various external changes (wasting indicators) that were observed on the various parts of embankments, changes that could be employed as the basic wasting data of coastal embankments for the study approach mentioned above.

Table 3.1 -- Visible Changes Showing the Wasting (Wasting Index) of Coastal Embankment Parts and Related Causes of Embankment Breakdowns

表－3.1 海岸堤防各部の外見にみられる劣化をしめす変化（劣化指標）と関連する堤防の破壊原因

工種名称および外見にあらわれる劣化指標 (1)			要 (43)							因				備考 56
2 工種	3 形状および位置	4 外見にあらわれる劣化指標	波浪 44	[illegible] 45	高潮の堤内外水位差 46	[illegible]の進行 47	堤体土砂の土圧 48	堤体土砂の圧密沈下 49	堤体自重による[illegible]沈下 50	51 その他: 流れ 52	[illegible] 53	化学変化・風化 54	施工不良 55	
5 基礎工	形状 6	[illegible]との[illegible]の[illegible] 12	○											
		[illegible]石の[illegible]，散乱 13	○							○				
		[illegible]ブロックの[illegible]，散乱 14	○											
		[illegible]・[illegible] 15	○							○				
		沈下 16	○							○				
		はらみ出し 17												
7 表のり被覆工	形状 6	法線直角方向のはらみ出し 18				○							○	
		法線直角方向のはね出し 19												基礎工の[illegible] 57
		法線直角方向のへこみ 20						○					○	基礎工の[illegible]（[illegible]） 58
	材料（コンクリート） 8	角が欠けている 21	○								○			
		摩耗 22												（[illegible]による摩耗，化学変化，風化） 59
		亀裂 23	○								○			
		表面の[illegible] 24										○	○	[illegible] 60
	目地および継手 9	縦目地（法線方向の目地）の開き 25	○			○								（[illegible]によるはらみ出し） 61
		縦目地（ 〃 ）角欠け 26							○		○			（堤体土砂の不等沈下） 62
		縦目地（ 〃 ）上下ずれ 27							○				○	（ 〃 ） 〃
		縦目地（ 〃 ）[illegible]ずれ 28							○					（ 〃 ） 〃
		横目地（法線直角方向の目地）の開き 29							○		○			（堤体土砂の不等沈下） 〃
		横目地（ 〃 ）の角欠け 30	○						○					（ 〃 ） 〃
		横目地（ 〃 ）の上下ずれ 31							○				○	（ 〃 ） 〃
		横目地（ 〃 ）の[illegible]ずれ 32							○					（ 〃 ） 〃
		基礎工との打継手の開き 33												基礎工の沈下 63
		基礎工との打継手の角欠け 34	○								○			〃
		基礎工の打継手の上下ずれ 35											○	基礎工の沈下
		波返し工との打継手の開き 36						○	○					〃 基礎工の沈下
		波返し工との打継手のずれ 37						○	○				○	（場合によってある[illegible]） 64
		波返し工との打継手の角欠け 38												
	クラックの状態 10	法線方向のクラック 39		○				○						基礎工の沈下 63
		法線直角方向のクラック 40		○				○	○					
11 波返し工	形状 6	不[illegible] 41						○	○				○	（堤体の不等沈下） 65
		法線の出入り 42		○				○					○	
	材料（コンクリート） 8	角が欠けている 21	○								○			
		摩耗 22												[illegible]による摩耗，化学変化，風化 66

(Continued Table 3.1)

(2) 工種	工種名称および外見にあらわれる劣化指標 (1) (3) 名称および部位	(4) 外見にあらわれる劣化指標	(45) 原 因 波 浪 (43)	波浪の衝突 (44)	高潮の堤内外水位差 (46)	重車輌の通行 (47)	堤体土砂の土圧 (48)	堤体土砂の圧密沈下 (49)	堤体る盛による沈下 (50)	(51) その他 漏 れ (52)	漂流物 (53)	化学変化・風化 (54)	施工不良 (55)	備 考 (56)
(11) 波返し工	材料 (コンクリート) (8)	亀裂 (23)	○											
		鉄筋のさび (24)											○	鉄筋の腐食 (94)
	目地および継手 (9)	開き (69)						○	○					(堤体の不等沈下) (63)
		上下ずれ (70)						○	○				○	(〃) 〃
		前後ずれ (71)		○					○					(〃) 〃
	(10) クラックの状態	法線方向のクラック (39)						○	○					(堤体の不等沈下) 〃
		法線方向水平クラック (72)		○				○						
(67) 天端工	形状 (6)	不陸 (法線直角方向のクラックが少しあるがクラックが少ない) (73)						○	○					
		不陸 (法線直角方向のクラックが多く, 法線方向のクラックがある) (74)	△			○		○	○					堤体内に空洞あるいは空隙の存在が予想される (95)
		不陸 (コンクリート強度が低下, 割れている) (75)	△			○		○	○					堤体内の空洞あるいは空隙の規模がかなり大であることが予想される (97)
		不陸 (施工不良による) (76)											○	
	材料 (68)	角が欠けている (21)		○		○								剥落 (96)
		摩耗 (22)		○		○								走行車輌, 越波による摩耗, 化学変化, 風化 (97)
		損傷 (23)		○		○								走行車輌, 越波による (98)
	目地および継手 (9)	施工目地の開き (77)						○	○					(堤体内の空洞, 目地からの堤体土砂の吸い出し, 土砂の裏込石への侵入がある) (99)
		施工目地の角欠け (78)				○		○	○					(〃 〃 〃)
		施工目地の上下ずれ (79)						○	○				○	(〃 〃 〃)
		施工目地の出入ずれ (80)						○	○					(〃 〃 〃)
		波返し工との目地の開き (81)						○	○					波返しの破損 (100)
		波返し工との目地の上下ずれ (82)						○	○					(堤体土砂の吸い出し, 移動によるか) (100a)
		波返し工との目地の角欠け (83)		○		○		○	○					波返しの破損 (101)
		表のり工との目地の開き (84)				○	○	○	○				·	表のり工のはらみ出し (102)
		表のり工との目地の上下ずれ (85)				○	○	○	○				○	
		表のり工との目地の角欠け (86)				○		○	○					
	(10) クラックの状態	法線直角方向のクラックのみで少ない (87)		○		○		○	○					
		法線直角方向のクラックのみで多い (88)				○		○	○					堤体内に空洞, 空隙があるおそれがある (103)
		法線方向のクラック (39)				○		○						堤体内に空洞, 空隙が存在する (104)
		法線直角および法線方向のクラックがともにあり, クラックが多い (89)	△	△		○		○						
(104) 表のり被覆工	形状 (6)	法線直角方向のはらみ出し (90)				○	○		○				○	(走行車輌(漂流物)) (105)
		法線直角方向のはね出し (91)				○	○							(根固工の移動) (106)
		法線直角方向のへこみ (92)				○	○	○					○	(根固工の沈下, 消失) (107)
		目地の不良 (93)							○				○	
	材料 (68)	角が欠けている (21)												
		摩耗 (22)										○		化学変化, 風化 (54)
		損傷 (23)												
		鉄筋のさび (24)											○	鉄筋の腐食, かぶり不足 (108)

(Continued Table 5.1)

工種 (2)	形状および位置 (3)	外見にあらわれる劣化現象 (4)	設計 (43)	基礎の洗掘 (44)	高潮の堤内外水位差 (46)	自動車の通行 (47)	堤体土砂の土圧 (48)	堤体土砂の圧密沈下 (49)	堤体自重による地盤沈下 (50)	その他 (51): 流れ (52)	その他: 漂流物 (53)	その他: 化学変化・風化 (54)	その他: 施工不良 (55)	備考 (56)
法のり被覆工 (109)	目地および継手 (9)	縦目地の開き (112)				○	○							自動車の通行によるはらみ出し，根留工の移動 (125)
		縦目地の角欠け (113)							○					
		縦目地の上下ずれ (114)				○			○				○	
		縦目地の出入ずれ (115)							○					
		横目地の開き (116)							○					
		横目地の上下ずれ (117)							○				○	
		横目地の出入ずれ (118)						○	○					
		横目地の角欠け (119)							○					
		根留工との打継手の開き (120)				○	○							根留工の移動 (127)
		根留工との打継手の角欠け (121)				○	○							
		根留工との打継手の上下ずれ (122)				○	○		○				○	
	クラックの状態 (10)	法線方向のクラック (37)				○	○	○	○					根留工の移動　堤体内の空洞，空隙による[illegible] (128)
		法線直角方向のクラック (42)				○			○					
根留工 (110)	形状 (6)	法線直角方向のはらみ出し (40)				○	○							
		法線直角方向のはね出し (91)				○	○							
		法線方向の不陸 (103)							○					
	材料 (68)	角が欠けている (21)				○	○		○					
		摩耗 (22)										○		
		損傷 (23)												
		表面のあさび (24)												
	目地 (111)	施工目地の開き (77)							○					
		施工目地の角欠け (74)				○	○		○					
		施工目地の上下ずれ (79)							○					
		施工目地の出入ずれ (80)				○	○		○					
その他 (51)		パイピング (124)												
		車や走行交通によって堤体がうきる (125)												

Key (to Table 3.1):

1. Name of structure and visible indicator of wasting
2. Name of structure
3. Shape and location
4. Visible indicator of wasting
5. Foundation
6. Shape
7. Face spread armor
8. Material (concrete)
9. Ground site and adjacent area
10. Crack situation
11. Wave deflector
12. Destruction of connecting part to rock base
13. Burial, dispersion of bedding anchor rock armor
14. Burial, dispersion of wave dissipation block
15. Erosion
16. Sinking
17. Exposure
18. Exposure toward normal right angle direction
19. Protrusion toward normal right angle direction
20. Indentation toward normal right angle direction
21. Angular break
22. Abrasion
23. Damage
24. Surface rust
25. Breach of vertical ground site (normal direction of ground site)
26. Angular break of vertical ground site (normal direction of ground site)
27. Vertical slippage of vertical ground site (normal direction of ground site)
28. Cave-in inside the surface of vertical ground site (normal direction of ground site)
29. Breach of horizontal ground site (normal right angle direction of ground site)
30. Angular break of horizontal ground site (normal right angle direction of ground site)
31. Vertical slippage of horizontal ground site (normal right angle direction of ground site)
32. Cave-in inside the surface of horizontal ground site (normal right angle direction of ground site)
33. Breach between implaced joint and foundation
34. Angular break between implaced joint and foundation
35. Vertical slippage of implaced joint for foundation
36. Breach between implaced joint and foundation
37. Slippage of implaced joint from foundation
38. Angular break of implaced joint from foundation
39. Normal direction crack
40. Normal right angle direction crack
41. Erosion of soil
42. Normal indentation
43. Cause
44. Waves
45. Crashing waves
46. Internal and external water levels of embankment during high tide
47. Heavy vehicle traffic

(Continued Key to Table 3.1)

48. Earth pressure of embankment earth and sand
49. Compaction and sinking of embankment earth & sand
50. Sinking of base from weight of embankment
51. Others
52. Flow
53. Littoral material
54. Chemical change, weathering
55. Improper construction work
56. Remark
57. Shifting of foundation
58. Shifting of foundation (sinking, tilting forward)
59. (Abrasion, chemical change, and weathering from wave action and sand action)
60. Erosion of ferro-concrete/iron bars; inadequate covering
61. (Exposure from heavy vehicle traffic)
62. (Uneven sinking of embankment earth and sand)
63. Sinking of foundation
64. (Possibility depending on the structure)
65. (Uneven sinking of foundation)
66. Abrasion, chemical change, and weathering from wave action
67. Crown
68. Material
69. Breach
70. Vertical slippage
71. Slippage, front & back
72. Normal direction water level crack
73. Erosion of soil (very few or no crack of normal right angle direction)
74. Erosion of soil (many cracks of normal right angle direction; cracks of normal direction)
75. Erosion of soil (sinking & rupture of concrete block)
76. Erosion of soil (due to improper construction work)
77. Breach at work site
78. Angular break at work site
79. Vertical slippage at work site
80. Slippage below the surface of work site
81. Breach between wave deflector and ground site
82. Vertical slippage between wave deflector and ground site
83. Angular break between wave deflector and ground site
84. Breach between rear spread and ground site
85. Vertical slippage between rear spread and ground site
86. Angular break between rear spread and ground site
87. Only small number of cracks; all normal right angle direction cracks
88. Large number of normal right angle direction cracks
89. Large numbers of both normal right angle and normal direction cracks
90. Exposure of normal right angle direction
91. Protrusion of normal right angle direction
92. Indentation of normal right angle direction
93. Soil erosion of shoulder
94. Erosion of ferro-concrete/iron bars
95. Presumed existence of weep holes and gaps in embankment

(Continued Key to Table 3.1)

95a. Presumed weep holes & gaps in embankment to be fairly large
96. Overtopping waves
97. Abrasion, chemical change, & weathering from vehicle traffic and overtopping waves
98. Due to vehicle traffic & overtopping waves
99. Drainage of embankment earth & sand from weep holes in embankment and crown; seepage of soil & sand into rip-rap
100. Forward tilting of wave deflector
100a. (Drainage of embankment earth & sand; possibly from shifting)
101. Backward tilting of wave deflector
102. Exposure of rear spread
103. Most probable existence of weep holes and gaps in embankment
104. Definite existence of weep holes and gaps in embankment
105. (Heavy traffic - heavy loads)
106. (Shift of bedding anchor)
107. (Sinking, forward tilting of bedding anchor)
108. Erosion of ferro-concrete/
1 iron bars; inadequate covering
109. Rear spread armor
110. Bedding anchor
111. Ground site
112. Break of vertical ground site
113. Angular break of vertical ground site
114. Vertical slippage of vertical ground site
115. Slippage below the surface of vertical ground site
116. Breach of horizontal ground site
117. Vertical slippage of horizontal ground site
118. Slippage below the surface of horizontal ground site
119. Angular break of horizontal ground site
120. Break between bedding anchor and implaced joint
121. Angular break between bedding anchor and implaced joint
122. Vertical slippage of implaced joint with bedding anchor
123. Erosion of soil of normal direction
124. Pipings
125. Humming noise of embankment from wave action and vehicle traffic
126. Exposure and shifting of reinforced bedding from vehicle traffic
127. Shifting of bedding anchor
128. Shifting of bedding anchor due to internal weep holes and gaps of embankment

IV. On the Survey of Existing Waste Conditions of Coastal Embankments

In Chapter III, we first examined the breakdown process of coastal embankments as well as the visible embankment changes that occur in this process and then presented the "points" /per text/ to watch in the breakdown process, i.e., the things to notice in the detection of embankment wasting. These "points" to be sure will show the existing waste condition of an embankment, but they will not show the extent of the wasting that has occurred nor the time span before the wasting will cause the collapse of the embankment. The above is to say that although the post-construction changes (wasting index) that surface on an embankment will serve as wasting signs, they will not show how well an embankment can withstand the onslaught of an unusual weather that brings strong waves, high tides, heavy rainfall and floods, high water levels, etc. The answer to this question lies in thorough and extensive research of the calamities that had occurred to embankments in the past. Sad to report, however, the types of data required for this research are not readily available; that is to say, in most cases, no information is available on the environmental conditions (especially data on wave force) that prevailed at the time of the past calamity strikes and even data on the embankment structures that were damaged or destroyed by a calamity as well as the conditions of the soil at the time are difficult to obtain. The same kind of problem is also being encountered in the gathering of data on the damaged structures that were reconstructed or restored after a disaster. The difficulty in these cases could be attributed to the placement of top priority on speedy restoration work to safeguard the life and property of the people living to the rear of the damaged area and to the relegation of disaster data collection function to secondary importance. Needless to say, there are infinite varieties of disaster damages, necessitating meticulous collection of pertinent data over a long period of time to clearly grasp the relationship between the developing wasting situations and the external forces, such as wave action, that bring about these development. Normally, an important source for these data is the maintenance and control files kept on embankments. Unfortunately, there was much to be desired in the files that were made available to compound the work that we had to undertake in this study.

In the face of the situations discussed above, we undertook the on-the-spot surveys with the focus of attention placed on the following: (1) acquiring accurate information on the existing waste conditions of the coastal embankments and sea walls; (2) testing the waste conditions of the structural materials of the coastal embankments and sea walls; and (3) seeking the comprehensive judgments of specialists on the waste conditions.

These on-the-spot data were employed as basic information in the preparation of the wasting index for the coastal embankments and sea walls.

A. Acquiring Accurate Information on the Existing Waste Conditions of Coastal Embankments and Sea Walls

To acquire accurate information on the existing waste conditions of coastal embankments and sea walls, the cooperation of the officials in charge of the coastal areas of Mie, Ishikawa, Toyama, Yamaguchi, and Oita prefectures was sought. From each of them, we obtained a listing of the so-called "rokyuka [old and useless]" embankments and sea walls located in his area of jurisdiction. From these listings, certain ones were selected for the on-the-spot surveys that were conducted. Those surveyed are listed in Chart 5.1. Inasmuch as these listings that were submitted were based on a vague guidance, "...those embankments believed to have become 'rokyuka'", many of the embankments and sea walls that were listed did not meet the requirements of the term, "rekka," as defined in section II and as used in this study; even embankments/sea walls scheduled for disaster renovation work were included in these listings.

There were a number of factors that compounded the problem of acquiring accurate information on the existing waste conditions of embankments and sea walls. The limited scope of the investigation conducted and the insufficient number of sample breakdown cases that fell within the definition of the term, "rekka," were two of these factors. With regard to the latter, the primary cause could be traced to the difficulty of providing clear-cut guidance to the aforementioned officials in the selection of the embankments and sea walls to be listed. This stemmed from the fact that at that time, there was no clear understanding on how to define the term, "rokyuka," nor how to distinguish the difference between this term and the term, "rekka," and how this selection should be made. Another factor that contributed to the problem on hand was the unavailability of construction data on old embankments and sea walls due in many cases to their misplacement or to their filing in archives to make their accessibility difficult.

The difference of opinions on the term, "rokyuka," among the officials responsible for the maintenance and control of embankments and sea walls (also true among the officials who were asked to prepare the listings) as well as the abstract nature of the question itself, was the primary reason, it is believed, that made it difficult for us to gain the full understanding of the top government officials in charge of coastal affairs on the purpose

of this study. This failure was due for the most part to the poor explanation that was provided, but the very fact that we failed to gain this understanding did prove that there were differences of opinions on the urgency of "rokyuka" or "rekka"; that is to say, the seriousness of the wasting conditions of embankments and sea walls. That we were able through this study to alert those who are concerned on the seriousness of the situation is a matter of great satisfaction to us.

B. Testing the Waste Conditions of the Structural Materials of Coastal Embankments and Sea Walls.

We conducted careful on-the-spot surveys of concrete, the main material used for embankments and sea walls. The surveys undertaken included surface observations, compression strength test via "SHIYUMITTO" (Schmidt?) hammer, concrete quality evaluation via supersonic test method, and concrete material test via core boring of front surface. The findings were reported in Issue No 142, Technical Note of the Port and Harbor Research Institute.

C. Comprehensive Judgments on the Wasting of Coastal Embankments and Sea Walls

This study was undertaken with the primary objective of developing a method that can correctly evaluate and index the visible wasting changes that occur to embankments and sea walls on the basis of scientific and rational approach. If successful, this can be a valuable contribution to the task of determining the maintenance and control, or repair work that must be performed on embankments and sea walls to safeguard the precious life and property of the people residing in the area. Although the adoption of rational decisions on the visible wasting changes that occur to embankments and sea walls posed no serious problem, the task of indexing these changes to set up a wasting index was by no mean an easy one to achieve.

The study undertaken included careful review of the general concept on embankment and sea wall wastes as well as the significance attached to these wastes, on-the-spot investigation and confirmation of wastes, and examination of the methods to index these wastes.

The designs of embankments and sea walls differ greatly from those for the structures found within a harbor or port. Inasmuch as very few analysis work had been conducted in the past on the response behaviors of embankments and sea walls, their handling under the principle of dynamics was made extremely difficult. For

this very reason, the decision made in the past on the specifications for the parts and materials of embankments and sea walls had to be based on the well-established /General?/ Structural Specifications Manual. Because of the above, therefore, there was no way to verify the observed wastes of the embankments and sea walls on the basis and under the concept of structural dynamics. No provision was made in this study to conduct some kind of an experimental research to tackle the above problem and as a result, it became necessary to select an alternative method to achieve the objective in mind. The approach chosen was to strive for a comprehensive judgment /of technical specialists?/ on the breakdown signs, such as visible cracks, slippage at the ground site, etc., and waste conditions of structural materials of embankments and sea walls and then for the estimates of the extent/degree of these wastes from the standpoint of structural stability.

The following are some of the reasons that prompted the adoption of the above approach:

a. The decision on the parts and materials of the coastal structures had not been based on the concept of structural dynamics, etc., and thus, there was no way to obtain sufficient scholarly verification of the structural destruction.

b. Although no information was available on the theoretical basis of the comprehensive judgment offered by the technical specialists with coastal engineering knowledge and practical experience on the structural designs of embankments and sea walls, the judgment appeared accurate and reliable.

c. There was an absence of clear understanding on the concept of wasting from the very beginning and yet no program was conceived nor implemented to correct the situation.

The appraisal formula employed in the comprehensive judgment offered by the aforementioned technical specialists was the 5-category evaluation formula shown in Table 4.1.

This appraisal method and the accompanying discussion on the basis used for the judgment /TN: No explanation for the method or the discussion given/ helped to better understand the concept of wasting and led to the method of grouping the visible changes that were noted on subsequent embankments, etc., that were examined to estimate the wastes.

The 5-category evaluation formula showing the assessed waste conditions is given in Table 4.1.

Table 4.1 - Comprehensive Evaluation Standard of Embankments and Sea Walls

Evaluation Symbol

Evaluation

表－4.1 堤防・護岸の総合的評価基準

評価	評価内容	
A	完全である	In excellent condition
B	やや完全である（普通）	In relatively good condition (normal)
C	このままでも使用できないではない	Not impossible for use as is
D	多少の修理をすれば使用できる	Usable with some repair
E	改造が必要である	Reconstruction necesary

V. Existing Visible Wasting Conditions of Coastal Embankments and Sea Walls

Existing visible wasting conditions of the coastal embankments and sea walls and the findings of the on-the-spot surveys that were conducted to evaluate the extent of the wastings that had occurred to structures are shown in Chart 5.1-Chart 5.28, and Table 5.1-Table 5.2. The summary of facilities surveyed is given in Table 5.1. Charts 5.1-5.28 are cross-section drawings of the facilities surveyed in Yamaguchi, Oita, Ishikawa, Toyama, and Mie prefectures. Photographs 5.1-5.121 show snapshots of the visible changes that were observed on the various facilities surveyed. The photographing was focussed on those subjects that could be categorized as wasting indicator. Table 5.2 shows the existing coastal embankment wastesthat were observed per checklist of wasting index discussed in III C above.

Table 5.1 - Summary of Facilities Surveyed

Name/Symbol of Harbor — Type of Structure — Year Constructed (Number of Years) — Overall Evaluation — Chart No — Remark

In the column, 堤防=embankment 護防=sea wall

("Kanchi" [sic] block)

(masonry)

In the column, S=Showa; for the year, add 25; e.g., S 35 equals 35+25, or 1960.

表-5.1 調査施設一覧

港名	構造種別*	建設年（経過年数）	総合的評価	図番	備考
A	堤防（石積）	S 35 (11)	C	図-5.1	
B	堤防（石積）	S 31 (15)	D	図-5.2	
C	堤防（石積）	S 30 (16)	E	図-5.3	
D	堤防（石積）	S 26 (20)	D	図-5.4	
E	護岸（間知ブロック）	S 34 (12)	C	図-5.5	
F	護岸（石積）	S 30 (16)	E	図-5.6	
G	護岸（石積）	S 5 (41)	D	図-5.7	
H	護岸（石積）	S 2 (44)	E	図-5.8	
I	堤防	S 29~35 (17~11)	B	図-5.9	
J	堤防	S 29~35 (17~11)	C	図-5.10	
K	堤防	S 31 (15)	B	図-5.11	
L	堤防	S 29 (17)	B	図-5.12	
M	堤防	S 29 (17)	D	図-5.13	
N	堤防	S 34 (12)	C	図-5.14	
O	堤防	S 25~32 (21~14)	D	図-5.15	
P	堤防	S 25~32 (21~14)	D	図-5.16	
Q	堤防	S 28 (18)	D	図-5.17	
R	護岸	S 34~37 (12~ 9)	E	図-5.18	
S	護岸	S 7 (39)	C	図-5.19	
T	護岸	S 23 (23)	D	図-5.20	
U	護岸	S 32 (14)	E	図-5.21	
V	護岸	S 34 (12)	C	図-5.22	
W	護岸	S 4 (42)	E	図-5.23	
X	護岸	S 20 (26)	B	図-5.24	
Y	護岸	S 38 (8)	B	図-5.25	
Z	護岸	S 32 (14)	E	図-5.26	
Z-1	護岸	S 30 (16)	D	図-5.27	
Z-2	護岸	S 40 (6)	D	図-5.28	

* （ ）内は表のり被覆工の種類を示し，無記入はすべてコンクリート被覆

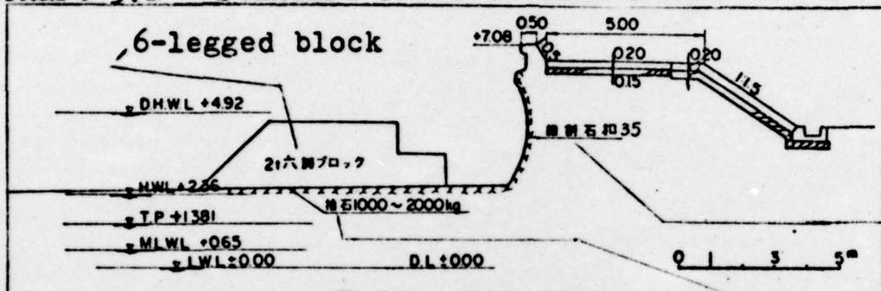
*Information enclosed in parenthesis indicates the type of face spread armor; where not given, the armor is concrete armor.

1. "A" Harbor: Embankment

Embankment located on the west side of Ise Wan; very little wave disturbance but eroded coast with six-legged block to the front as well as jetty; completed 60 years ago; survived Ise Wan typhoon with no damage; farmland and farm homes located to the rear; embankment face spread, "kanchi" [sic; can also be read, "mashiri/majiri", to be a possible Anglification of "module"] masonry, and others, three layer concrete; hair cracks at 3-5 m interval in wave deflector; crown used for road but no sinking; cracks at 3-5 m interval between crown and wave deflector; a very secure embankment for a masonry embankment.

Chart 5.1 - Standard Cross-section Sketch of "A" Harbor Em-

6-legged block



Mixed broken stone restraining [wall?]

Rip-rap

図 - 5.1 A港堤防標準断面図

写真 - 5.1 全景

Photo 5.1 - General View

写真 - 5.2 石積の状況(練石積)

Photo 5.2 - Condition of Masonry (scoured masonry)

写真 - 5.3 波返し工のクラック

Photo 5.3 - Crack of Wave Deflector

写真 - 5.4 天ば工のクラック

Photo 5.4 - Crack of Crown

2. "B" Harbor: Embankment

Embankment located on the south side of Ise Wan at the mouth of Isuzu Gawa (river); almost no wave disturbance; farmland and farm homes located to the rear; entire embankment surface, "kanchi" masonry, and crown, concrete (at the present time, asphalt); rear spread, sown mixed beach grass; below "kanchi" masonry, ground site packed concrete peeled off and sank to same level as water level to develop crevice, creating erosion danger to embankment earth and sand; crown used heavily by traffic, causing 7 cm sinkking but now paved with asphalt.

Photo 5.2 - Standard Cross-section Sketch of "B" Harbor Embankment

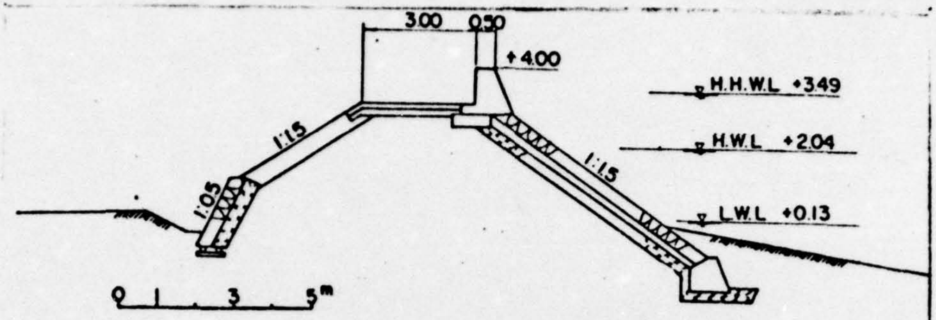


図-5.2 B港堤防標準断面図

写真-5.5 全景

ot 5.5 -
ne.al View

写真-5.6 石積の状況（練石積）

Photo 5.6 - Masonry Condition (scoured masonry)

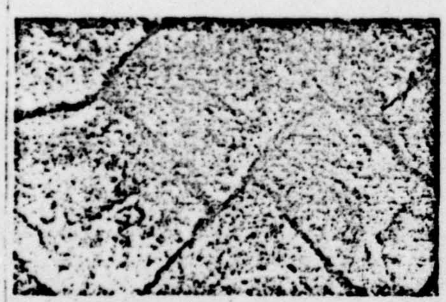


写真-5.7 石積のゆるみ

Photo 5.7 - Loosened Masonry

写真-5.8 上部コンクリート無破壊試験の状況

Photo 5.8 - Testing Scene of Upper Portion of Undamaged Concrete

3. "C" Harbor: Embankment (Masonry)

Embankment located on the southeast side of Kii pen deep inside the Owase Wan; fairly strong in-flow of waves from Kumano Nada, but partly abated by Benzai Island located to the front; patty fields, farmland, and railroad located to the rear; whole embankment constructed of coffer stones; packed concrete at ground site below the coffer stone pile peeled off; cracks at ground site; erosion of coffer stones in spots, creating threat of possible erosion of embank- earth and sand; front reinforced bedding covered with six-legged concrete block.

Chart 5.3 - Standard Cross-section Sketch of "C" Harbor Embankment

ix-legged bl ck (cover-ng)

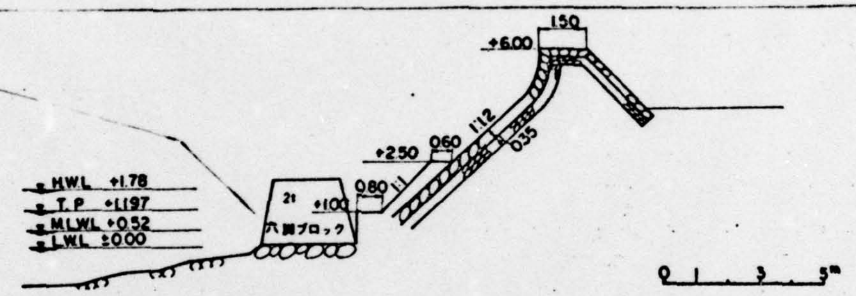


図-5.3 C港堤防標準断面図

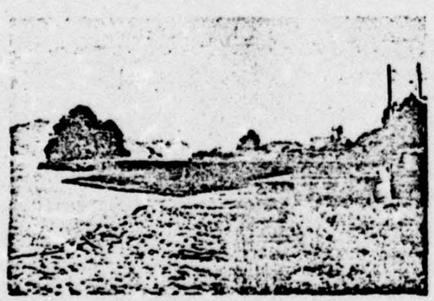


写真-5.9 全景（天ば工）

Photo 5.9 - General View (crown)

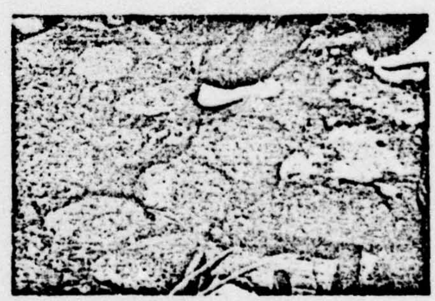


写真-5.10 天ば部の状況

Photo 5.10 - Condition of Crown

写真 - 5.11 表のり面（石積）

Photo 5.11 - Face Spread (masonry)

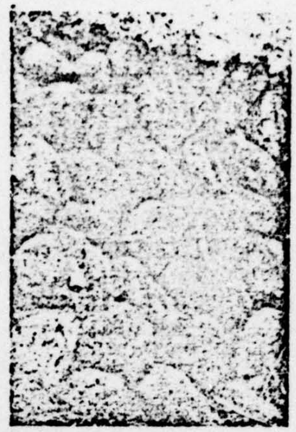


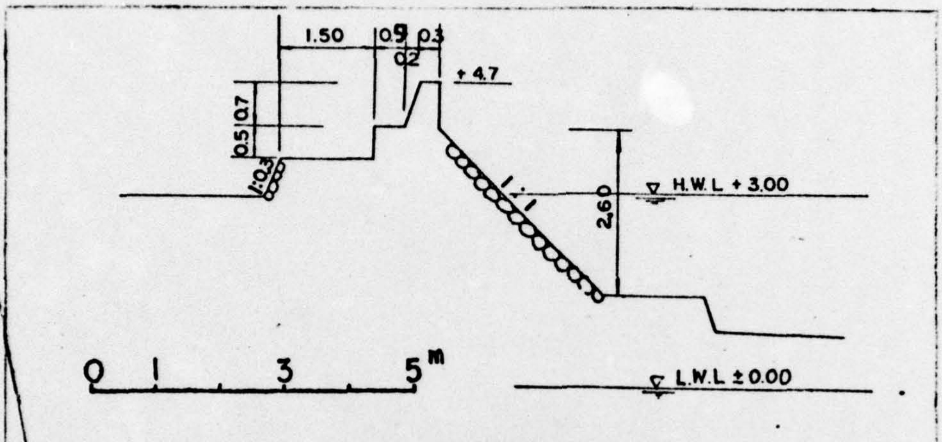
写真 - 5.12 表のり面の状況

Photo 5.12 - Condition of Face Spread

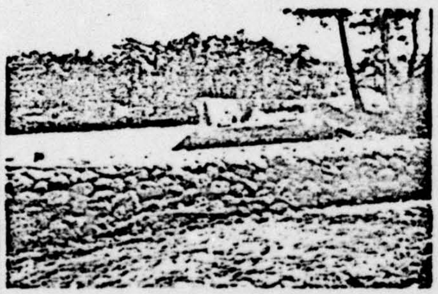
4. "D" Harbor: Embankment (Masonry)

Embankment located north of Kunisaki peninsula on the south side of Suo Nada; believed no exposure to strong wave action; constructed in 1952 as a subsidized project; face spread, "kanchi" masonry, and crown and rear spread, covered with growing mixed grass; face spread, exposed and shows depression; ground site packed concrete peeled off, showing run off of sea water to indicate possible erosion of embankment earth and sand; angular break of wave deflector's concrete joint; wave deflector shows abrasion; shows normal right angle direction crack.

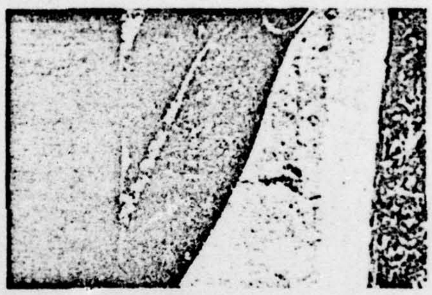
Chart 5.4 - Standard Cross-section Sketch of "D" Harbor Embankment



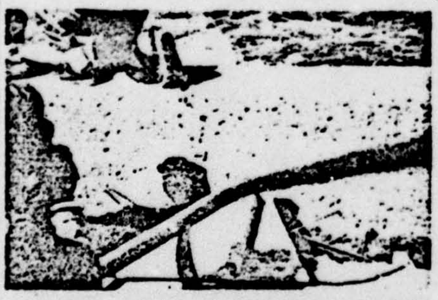
図－5.4 D港堤防標準断面図



写真－5.13 堤防断面



写真－5.14 波返し工のクラック（上側）



写真－5.15 波返し工のクラック（背後）

Photo 5.13 - Cross-section View of Embankment

Photo 5.14 - Wave Deflector Crack (upper side)

Photo 5.15 - Wave Deflector Crack (back side)

5. "E" Harbor: Sea Wall

Sea wall located on the southwest side of Ise Wan inside an inlet to be free from wave disturbance; depth of water to the front, about 1 m; spread shows crack; farm homes and farmland located to the rear; lower part, "kanchi" block mound showing few abrasions; angular break and damage observable in pile joints of block and concrete and additional breakdown could develop erosion of fill; crack in sectional direction but small so should not develop into big problem; heavy traffic and loads on crown caused sinking; cracking and angular breaks in crown, particularly in corner and at angle.

Chart 5.5 - Standard Cross-section Sketch of "E" Harbor Sea Wall

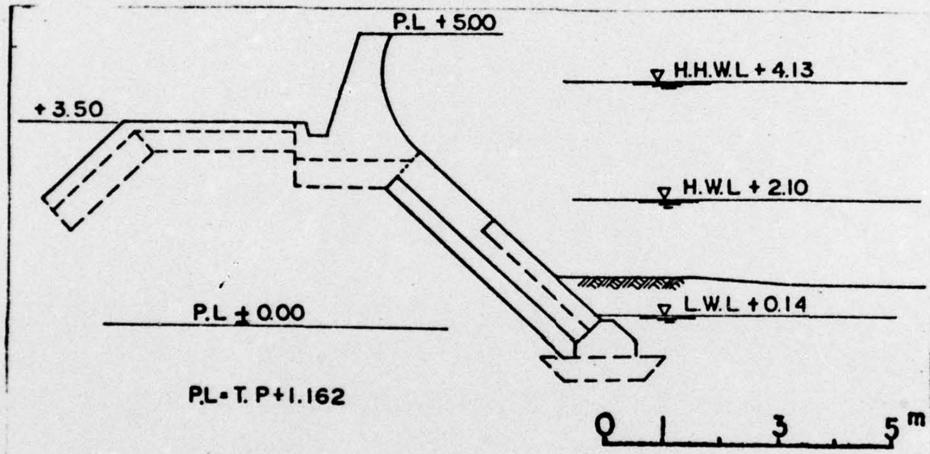


図-5.5 E港護岸標準断面図

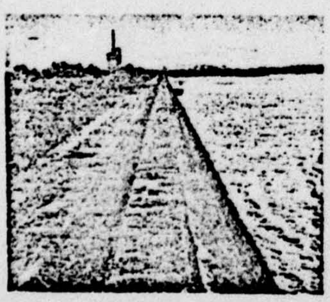


写真-5.16 全景

Photo 5.16 - General View

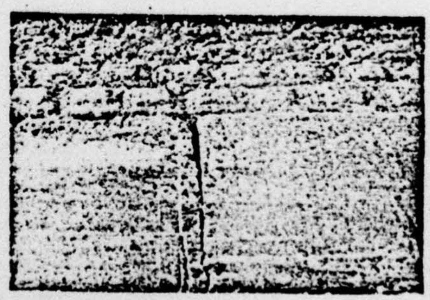


写真-5.17 表のり目地付近の状況

Photo 5.17 - Condition Near Face Spread Ground Site

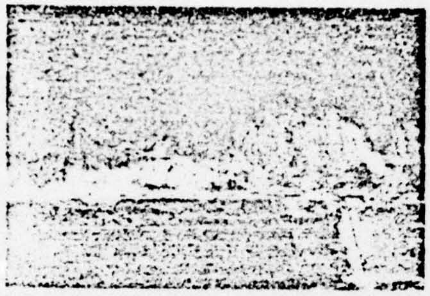


写真-5.18 表のり目地付近のエフロレッセンス

Photo 5.18 - Efflorescence Near Face Surface Ground Site

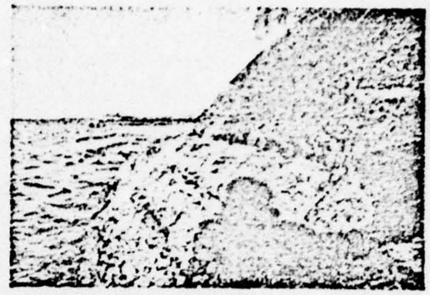


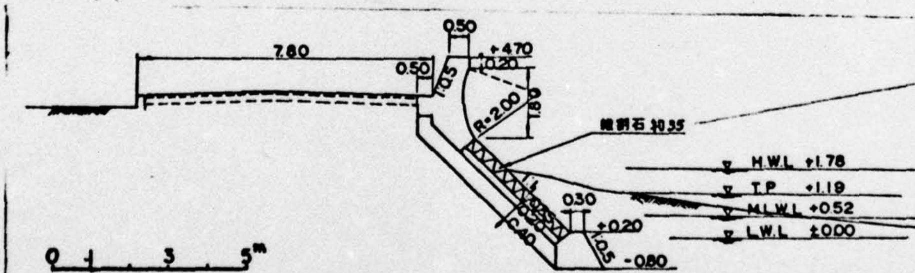
写真-5.19 表のり目地付近の状況

Photo 5.19 - Condition Near Face Spread Ground Site

6. "F" Harbor: Sea Wall

Sea wall located on the southeast side of Kii peninsula at the innermost site of an inlet ; facing Kumano Nada and thus not exposed to direct wave action but believed to be exposed to heavy diffraction waves; road located to the rear and bottom of sea to the immediate front comprised of small rocks; water level crack at ground site caused by the sinking at 20 m section due to "kanchi" masonry, creating danger of erosion of filled earth and sand; repair plan including the raising of crown and the laying of front concrete layer adopted and scheduled to be implemented soon.

Chart 5.6 - Standard Cross Section Sketch of "F" Harbor Sea Wall



Mixed broken stone restraining [wall?]

図-5.6 F港護岸標準断面図

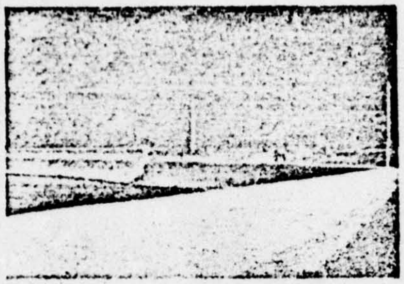


写真 - 5.20　全景

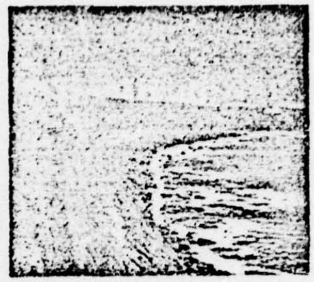


写真 - 5.21　表のりの状況

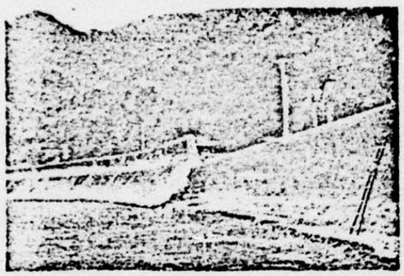


写真 - 5.22　表のりの状況

写真 - 5.23　波返し工の背後

Photo 5.20 - General View

Photo 5.21 - Condition of Face Surface

Photo 5.22 - Condition of Face Surface

Photo 5.23 - Rear of Wave Reflector

7. "G" Harbor: Sea Wall

Sea wall located near the eastern part of Noto peninsula; believed to be receiving heavy dosage of waves from Toyama Wan; roadway and dense farm homes located to the rear; constructed in 1930 with "kanchi" masonry, but lower section reinforced with concrete in 1950; severe exposure of structural materials due to concrete abrasion and rubbing between poorly mixed concrete and small front stones; wave reflector cracks per 10 m block but no sign of slippage due to sinking; masonry concrete at ground site peeled off but believed no erosion of fill from ground site nor rock losses.

Chart 5.7 - Standard Cross-section Sketch of "G" Harbor Sea Wall

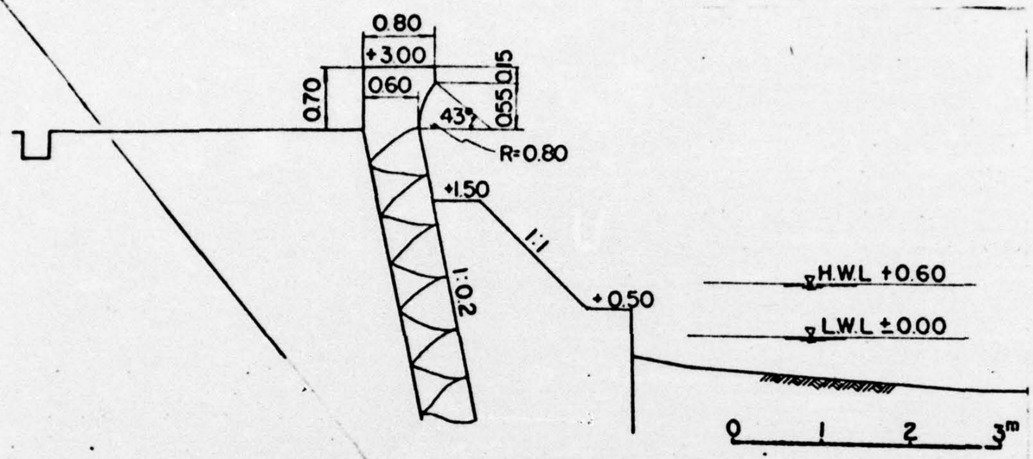


図 - 5.7 G港護岸標準断面図

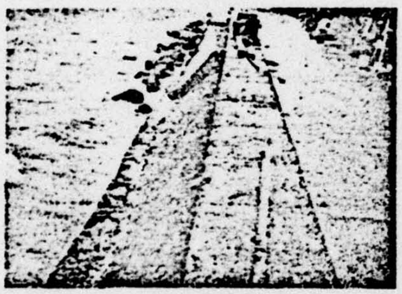


写真 - 5.24 全景

Photo 5.24 - General View

写真 - 5.25 表のり工の摩耗

Photo 5.25 - Abrasion of Face Spread

写真 - 5.26 水叩工の沈下(背後に水たまり)

Photo 5.26 - Sinking of Apron (water puddle to the rear)

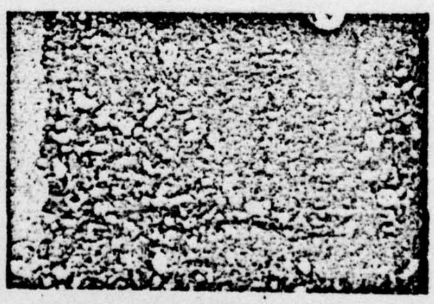


写真 - 5.27 波返し工のクラック

Photo 5.27 - Crack of Wave Reflector

8. "H" Harbor: Sea Wall

Sea wall located on west side of Noto peninsula; believed facing fairly heavy action of waves due to direct exposure to Japan Sea; part of a roadway and farmland and dense farm homes located to the rear; face spread, "kanchi" masonry; low wall height; wave deflector originally constructed of concrete but repaired with mortar for damage caused by exposure and inferior structural material but still peeling off; shifting of part of the reinforced bedding rocks observed; cave-ins of "kanchi" stones at two spots along the length of ground site due to use of "kanchi" masonry, indicating erosion of fills; no visible surface cave-in of apron observed; serious abrasion and structural material exposure of poorly mixed concrete wave deflector; very uneven crown top due to excessive use of roadway; backside of wave deflector seriously eroded by overtopping waves.

Chart 5.8 - Standard Cross-section Sketch of "H" Harbor Sea Wall

Site pile concrete

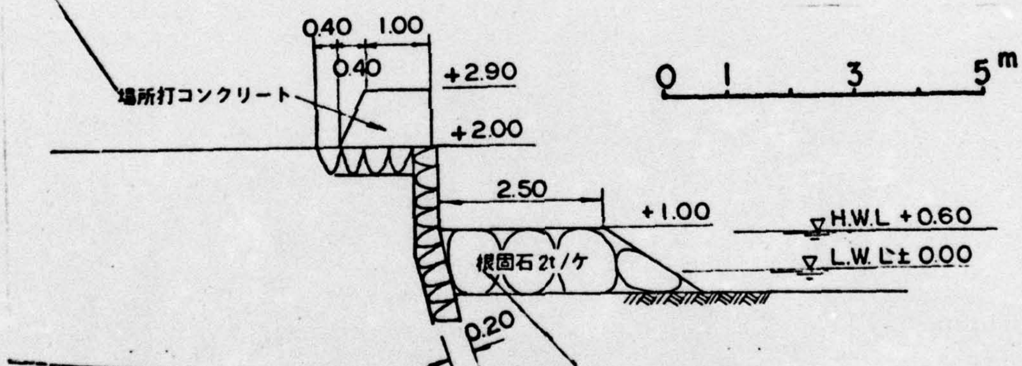


図-5.8 H港護岸標準断面図

Reinforced bedding rock

写真 - 5.28　全景

Photo 5.28-
General View

写真 - 5.29　波返し工の摩耗

Photo 5.29 - Abrasion of Wave Deflector

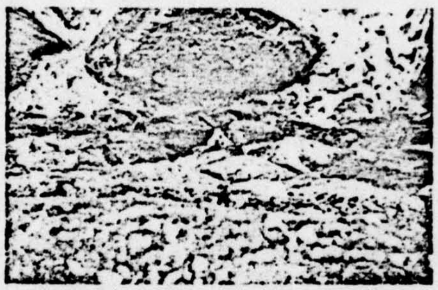


写真 - 5.30　表のり工間知石の抜け出し

Photo 5.30 - Erosion of "Kanchi" Stones of Face Spread

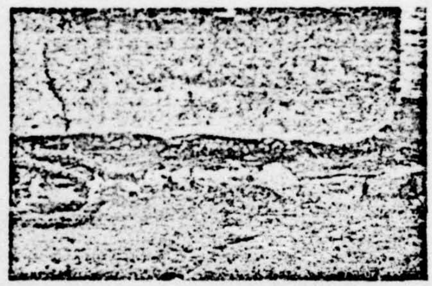


写真 - 5.31　波返し工接続部の損傷

Photo 5.31 - Damage of Wave Deflector Joint

9. "I" Harbor - Embankment

Embankment located on the west side of Ise Wan; about 200 m of front beach planted with reed, etc., indicating very little wave disturbance; road used by bathers, paddy fields, and farmland located to the rear; embankment constructed of three-layer concrete; face spread provided with small steps; ground site planted with mixed beach grass; structural materials exposed; crack observed in middle of a 10-m block; a 2-3 cm sinking observed in 20-m section of weak base of crown; corner and angular breaks in concrete and large crack in sectional direction; about a 3-cm breach in the berm of rear spread weak base.

Chart 5.9 - Standard Cross-section Sketch of "I" Harbor Embankment

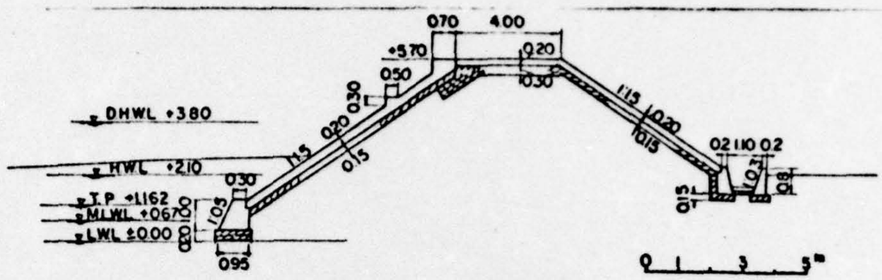


図 - 5.9 I港堤防標準断面図

写真 - 5.32 全景

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写真 - 5.33 表のり工のはらみ

Photo 5.33 - Exposure of Rear Spread

写真 - 5.34 天ば工の沈下, 角欠け

Photo 5.34 - Angular Break, Sinking of Crown

写真 - 5.35 表のり工のクラック

Photo 5.35 - Crack of Face Spread

写真 - 5.36 背のりと天ば工の目地のひらき

Photo 5.36 - Breach of Shoulder Spread and Crown at Ground Site

10. "J" Harbor: Embankment

Embankment located on the west side of Ise Wan; little wave disturbance observed but the corner and angular embankment location could mean fairly concentrated action of waves; factories and dense homes located to the rear; vertical front face of embankment, three-layer concrete, but serious abrasion with forward tilting in several spots; crack observed in face spread; about 1-cm sinking as well as slippage of wave deflector; observed abrasion, cracks, and sinking in crown used as roadway.

Chart 5.10 - Standard Cross-section Sketch of "J" Embankment

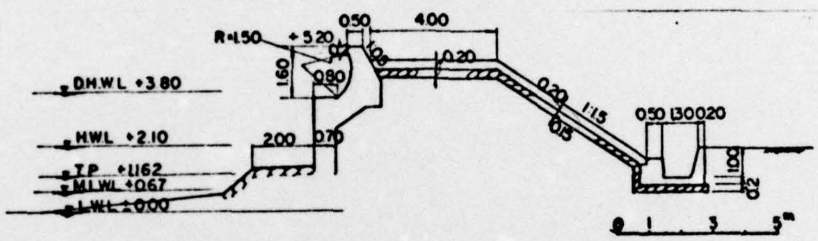


図 - 5.10 J港堤防標準断面図

写真 - 5.37 表のり工の状況

Photo 5.37 - Condition of Face Spread

写真 - 5.38 表のり工のクラック

Photo 5.38 - Crack of Face Spread

写真 - 5.39 表のり工のクラック

Photo 5.39 - Crack of Face Spread

写真-5.40 表のりコンクリートの摩耗

Photo 5.40 - Abrasion of Face Spread Concrete

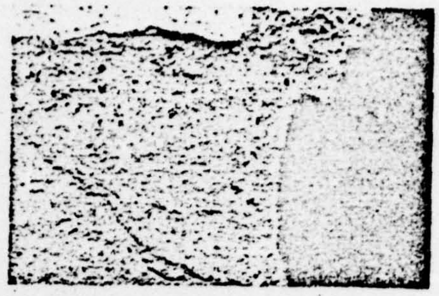


写真-5.41 天ば工コンクリートの摩耗

Photo 5.41 - Abrasion of Crown Crown

11. "K" Harbor: Embankment

Embankment located on the west side of Ise Wan; very little wave disturbance; racing boat docks located to the rear; embankment constructed of 3-layer concrete; relatively high embankment with rear spread standing about 5 m high; crack observed in face spread as well as rear spread; pitch of face and rear spreads, both about 3-5 m; both spreads, exposure in several places; sinking of crown, about 1 cm, and ground site, about 3 cm.

Chart 5.11 - Standard Cross-section Sketch of "K" Harbor Embankment

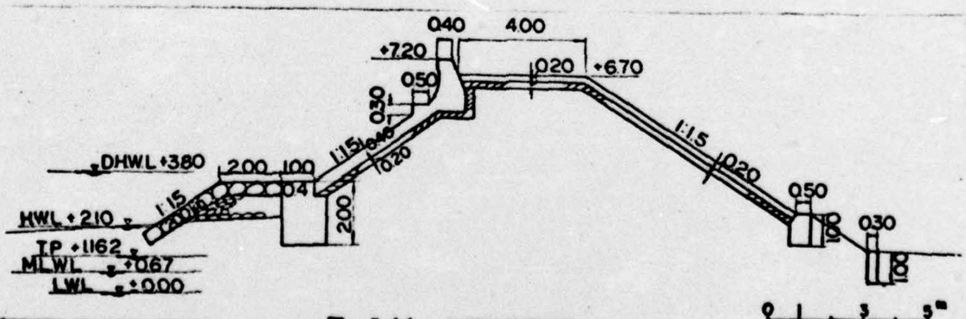


図-5.11 K港堤防標準断面図

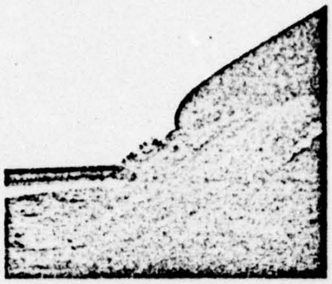


写真-5.42 表のり工

oto 5.42 -
ce Spread

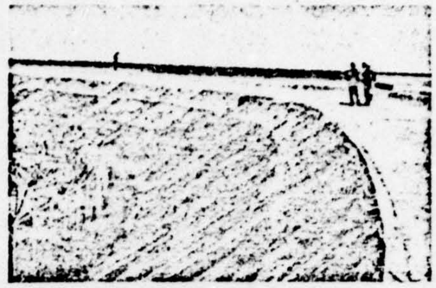


写真-5.43 裏のり工

Photo 5.43 -
Rear Spread

写真-5.44 表のり工のクラック

ot 5.44 -
ac. of
ce Spread

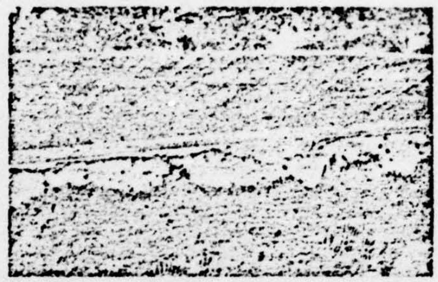


写真-5.45 波返し工背後にできた天ば工クラック

Photo 5.45 - Crown Crack That Developed Behind Wave Deflector

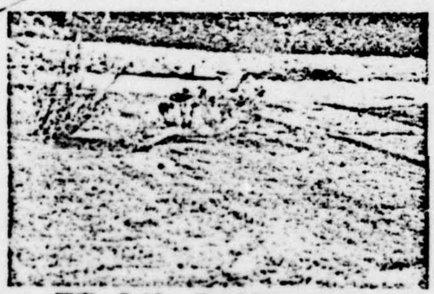


写真-5.46 裏のり工のクラック

Photo 5.46 - Crack of Rear Spread

写真-5.47 前面根固石の散乱

Photo 5.47 - Scattering of Reinforced Bedding Rocks on the Front Shore

12. "L" Harbor: Embankment

Embankment located on the southwest side of Ise Wan inside an inlet free of wave disturbance; water depth to the front, about ± 0 m; fish hatchery located to the rear; embankment whole front side, concrete covering; crown and rear spread, asphalt covering; cave-in of bedding anchor front part; ground site cave-in, about 8 cm; water level crack observed about 2 m below the upper part of embankment; wave deflector sinking, about 5 mm; several breaches in wave deflector due to poorly mixed concrete; no conspicuous changes observed for crown or rear spread.

Chart 5.12 - Standard Cross-section Sketch of "L" Harbor Embankment

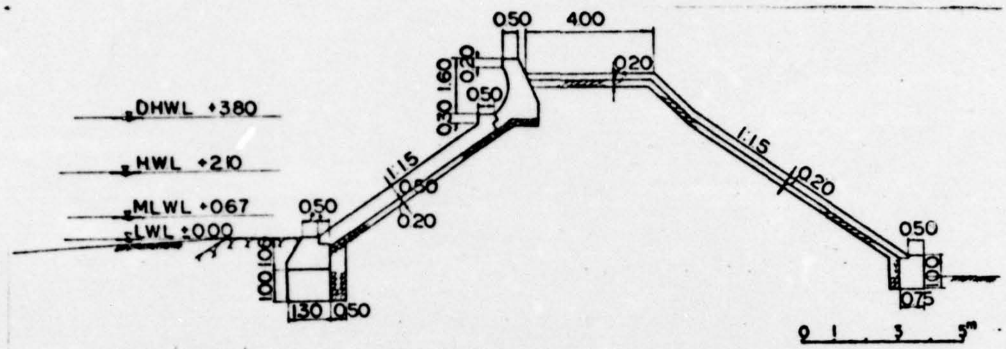
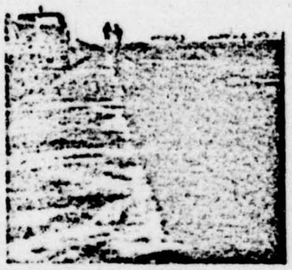


図-5.12　L港堤防標準断面図



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eral
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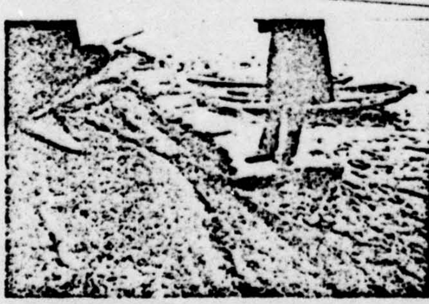
写真-5.48　全景

写真-5.49　表のりの目地のかけ

写真-5.50　表のり工のクラック

Photo 5.50 - Crack of Face Spread



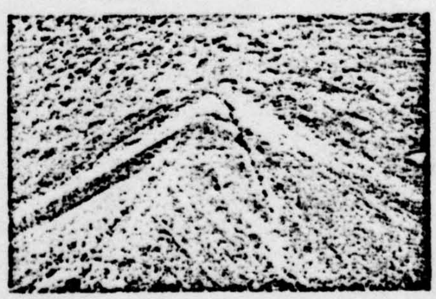


写真-5.51　表のり工の沈下によるずれ

写真-5.52　隅角表のり工のクラック

Photo 5.51 - Sinking Slippage of Face Spread

Photo 5.49 - Ground Site Break of Face Spread

Photo 5.52 - Corner Angular Crack of Face Spread

13. "M" Harbor: Embankment

Embankment located on the southern part of Shima peninsula inside the inner part of a bay that is opened to the south; because of location, only little disturbance from waves; fissure in face spread; road used by bathers and pine forest located to the rear; embankment, a low profile three-layer embankment with sunken weak base but showing no conspicuous uneven sinking; crown crack along 5 m pitch; indications showing ground site breach in several places; crack in wave deflector along 5 m pitch due to its alternate location with face spread; sinking of crown with water puddles in several places; very heavy sinking on the side of the sea with crack along 2-3 m pitch; vulnerable spots believed to be from the time of construction noted in rear spread.

Chart 5.13 - Standard Cross-section Sketch of "M" Harbor Embankment

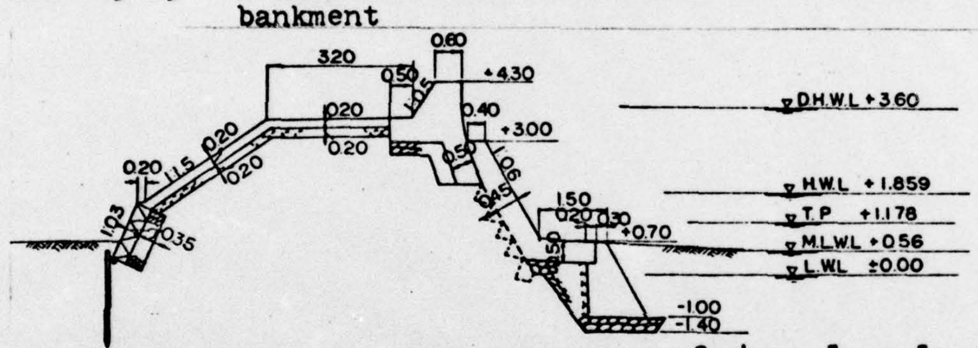


図-5.13 M港堤防標準断面図

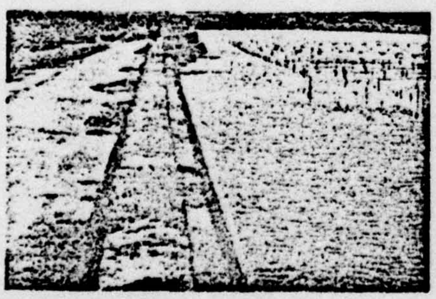


写真-5.53 全景

Photo 5.53 - General View

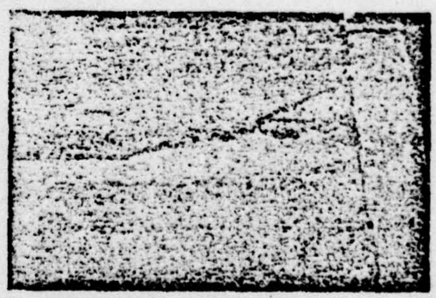
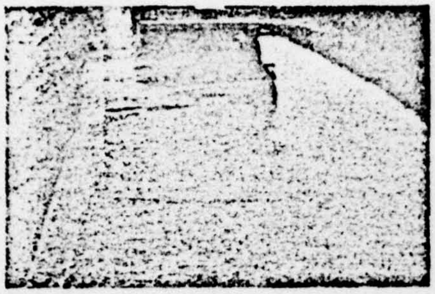


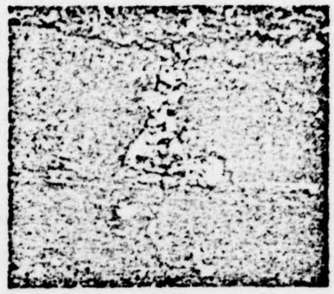
写真-5.54 天ば工コンクリートの損傷

Photo 5.54 - Damaged Crown Concrete



写真－5.55　天ば工の沈下，水溜り

Photo 5.55 - Sinking and Water Puddles of Crown



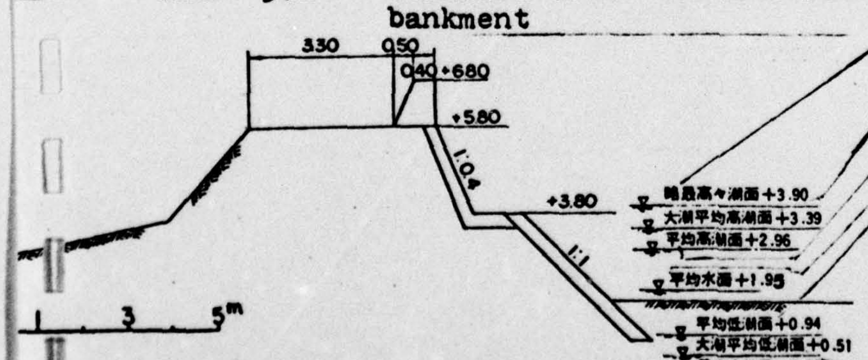
写真－5.56　裏のり工のクラック

Photo 5.56 - Crack of Rear Spread

14. "N" Harbor: Embankment

Embankment located northeast of Minato facing the inner harbor; believe no exposure to wave action; inoperative salt field located to the rear; small steps for reinforced bedding section of face spread; rear spread planted with mixed grass; crack in sunken weak base; sinking fairly deep for border and angular portions of face spread; in 40 m section of reinforced bedding, poor mixing/compostion observed in a number of places; large vertical and horizontal cracks in small steps of reinforced bedding; observed slippage of 2 cm front and back, and vertically for wave deflector; normal right angle direction crack in center of a 10 m long block as well normal direction water level crack in border and angular area; crown sinking, about 4 cm; normal direction crack in crown; cavity more visible than hole in crown; rear spread stable with rich growth of mixed grass.

Chart 5.14 - Standard Cross-section Sketch of "N" Harbor Embankment



- "Ryaku" [abridged?] maximum high tide surface
- flood tide mean high tide surface
- mean high tide surface
- mean water surface
- mean low tide surface
- flood tidemean low tide surface
- basic water level/ standard surface

図－5.14　N港堤防標準断面図

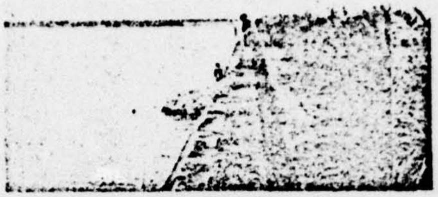


写真-5.57　全景

Photo 5.57 - General View

写真-5.58　表のり工小段のクラック

Photo 5.58 - Small Step Crack of Face Spread

写真-5.59　天ば工のクラック

Photo 5.59 - Crown Crack

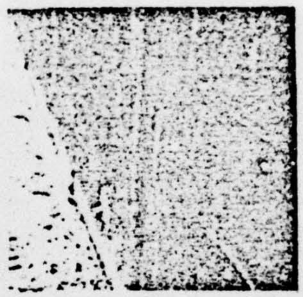


写真-5.60　波返し工法線直角方向のずれ

Photo 5.60 - Normal Right Angle Direction Slippage of Wave Deflector

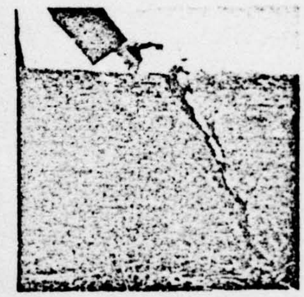


写真-5.61　波返し工の不等沈下によるクラック

Photo 5.61 - Crack from Uneven Settling of Wave Deflector

15. "O" Harbor: Embankment

An embankment in a district [not defined] with its west side adjacent to a river; believed action of waves against it fairly strong; reclaimed embankment with farm homes, paddy fields, and farmland to the rear; steep incline face spread with angular break in lower part; structural materials exposed in many places; many normal direction cracks in reinforced bedding small step section of corner angle section; several large right angle direction cracks in upper part of face spread; wave deflector with a front and rear aberration of 3-4 cm and an oblique crack; crown laid with blocks but cracks in blocks and crown sinkage due to heavy traffic; observed a number of places in corner angle section that had been restored from disaster damages.

Chart 5.15 - Standard Cross-section Sketch of "O" Harbor Embankment

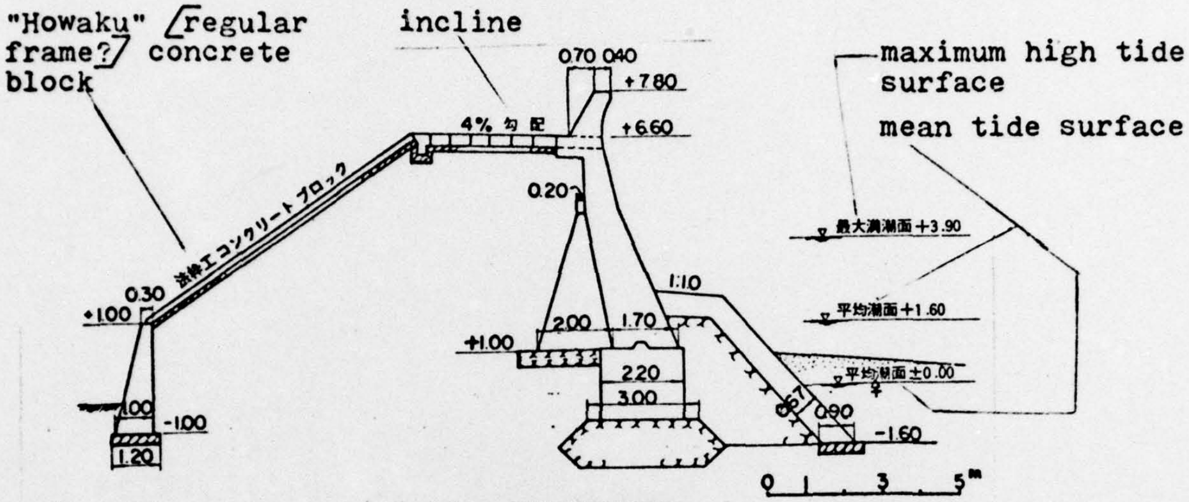


図-5.15 O港堤防標準断面図

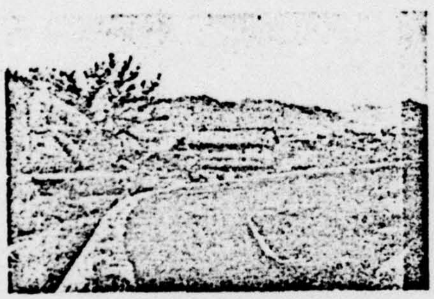


写真-5.62 全景

Photo 5.62 - General View

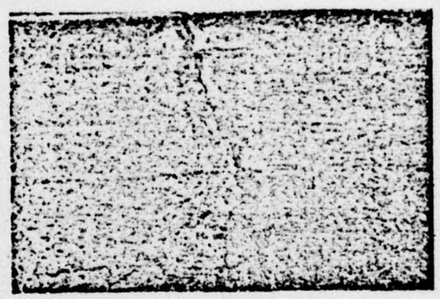


写真-5.63 波返し工のクラック

Photo 5.63 - Wave Deflector Crack

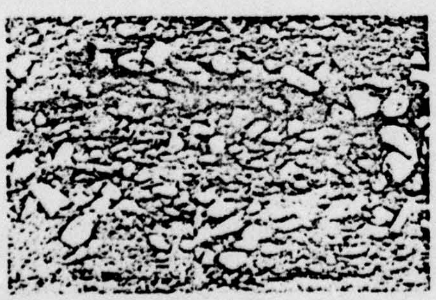


写真-5.64 表のり工小段部のコンクリートの損傷

Photo 5.64 - Small Step Section Damage of Face Spread

写真-5.65 表のり工小段部の内部捨石の露出

Photo 5.65 - Internal Rip-rap Exposure of Small Step Section of Face Spread

16. "P" Harbor: Embankment

Embankment located adjacent to "O" harbor coastal embankment; structurally about the same; poorly mixed concrete of face spread very conspicuous; a hole measuring 0.5 m deep, 0.5 m wide, and 2.5 m long observed in small step section of reinforced bedding; a 0.3 m deep hole also visible in upper part of normal surface; large crack in parallel normal line of small step section of reinforced bedding; many cracks in small steps of indented section; 2 cm aberration, both front and back of wave deflector; vertical aberration of about 2 cm for corner angle section; crack in normal right angle direction; sinking and break in blocks laid on crown due to heavy traffic; portion of rear spread block layers exposed and indented in several places.

Chart 5.16 - Standard Cross-section Sketch of "P" Harbor Embankment

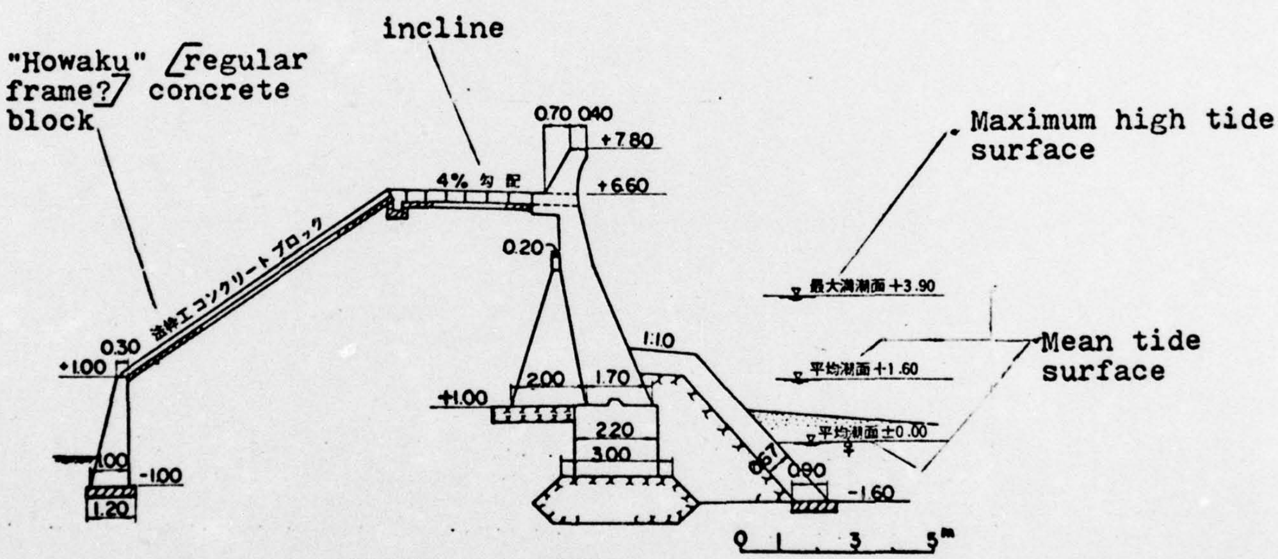


図 - 5.16 P港堤防標準断面図

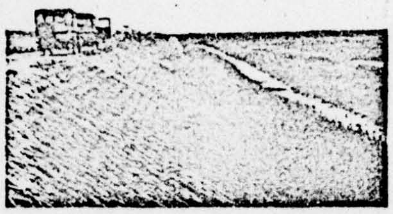


写真 - 5.66　裏のり工の状況（天ば，裏のりの不陸）

Photo 5.66 - Condition of Rear Spread (soil erosion of crown and rear spread)

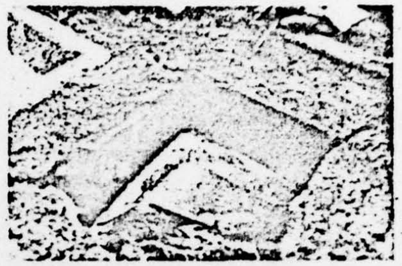


写真 - 5.67　裏のり工の吸出しによるブロック陥没

Photo 5.67 - Block Cave-in Due to Erosion [soil?] of Rear Spread

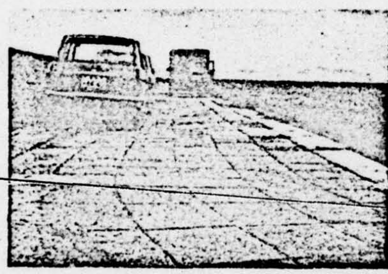


写真 - 5.68　天ばブロックの不陸

Photo 5.68 - Soil Erosion Crown Blocks

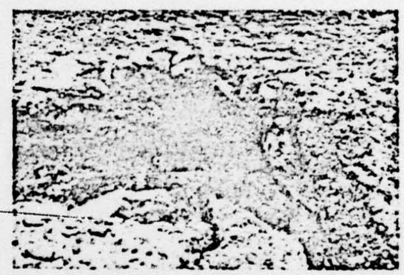


写真 - 5.69　表のり小段部のコンクリートの損傷

Photo 5.69 - Damage of Small Step Section of Face Spread

17. "Q" Harbor: Embankment

Embankment located south of Suo Nada; believed wave disturbance to be very little; reclaimed embankment with paddy fields in the rear; exposed face spread structures but no change in normal line; wave reflector concrete shows wear but no change; normal line right angle crack in corner angle section; block crack and 20 cm sinking of crown blocks due to dump car traffic on crown; rich growing mixed grass on rear spread.

Chart 5.17 - Standard Cross-section Sketch of "Q' Harbor Embankment

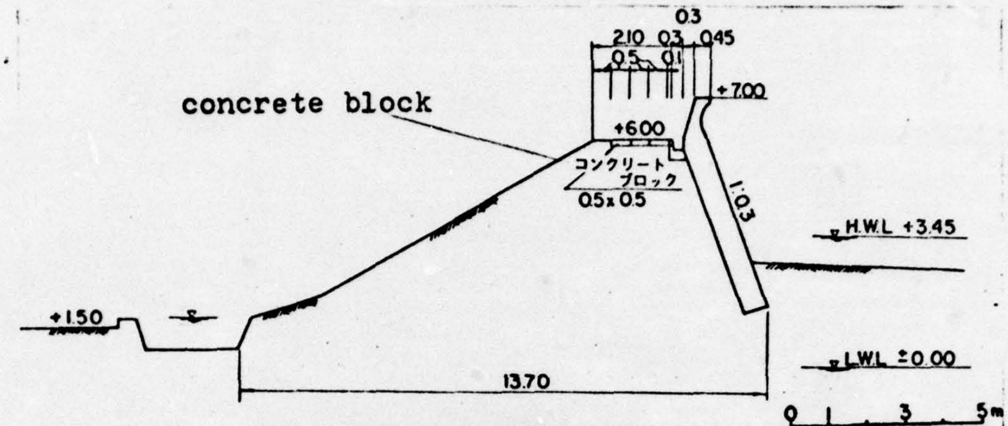


図-5.17 Q港堤防標準断面図

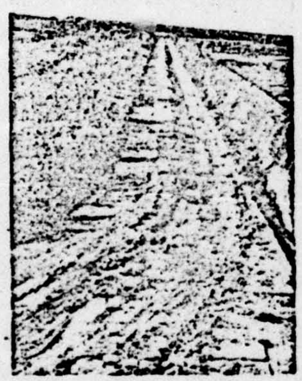


写真-5.70 全景
Photo 5.70 - General View

写真-5.71 天ば工の沈下，ブロックの割れ
Photo 5.71 - Sinking, Block Crack of Crown

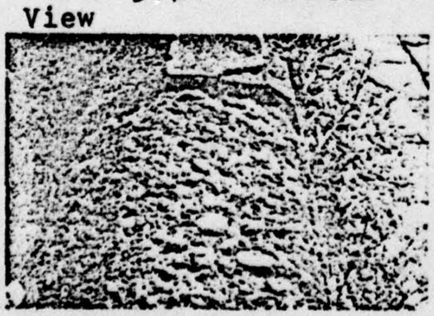


写真-5.72 波返しコンクリートの摩耗，沈下

写真-5.73 波返し工の目地のかけ

-Photo 5.72 - Abrasion, Sinking of Wave Deflector Concrete

Photo 5.73 - Wave Deflector Ground Site Break

18. "R" Harbor: Sea Wall

Sea wall located north of Shima peninsula; mouth of the harbor opens into Ise Wan but sea wall located deep inside the harbor and thus, the occurrence of strong wave action appears fairly remote; busy trunk railroad line causing heavy traffic located to the immediate rear; vertical concrete parapet constructed along railroad line but its base adjacent to river mouth and thus relatively weak, causing uneven sinking of serious nature; a small pool located between sea wall and rear railroad line; large crack in concrete parapet as well as angular break caused by friction in several places; face spread: step concrete blocks but serious uneven sinking; about a 4-cm breach between face spread blocks and parapet; serious abrasion of tidal [river?] section concrete.

Chart 5.18 - Standard Cross-section Sketch of "R" Harbor Sea Wall

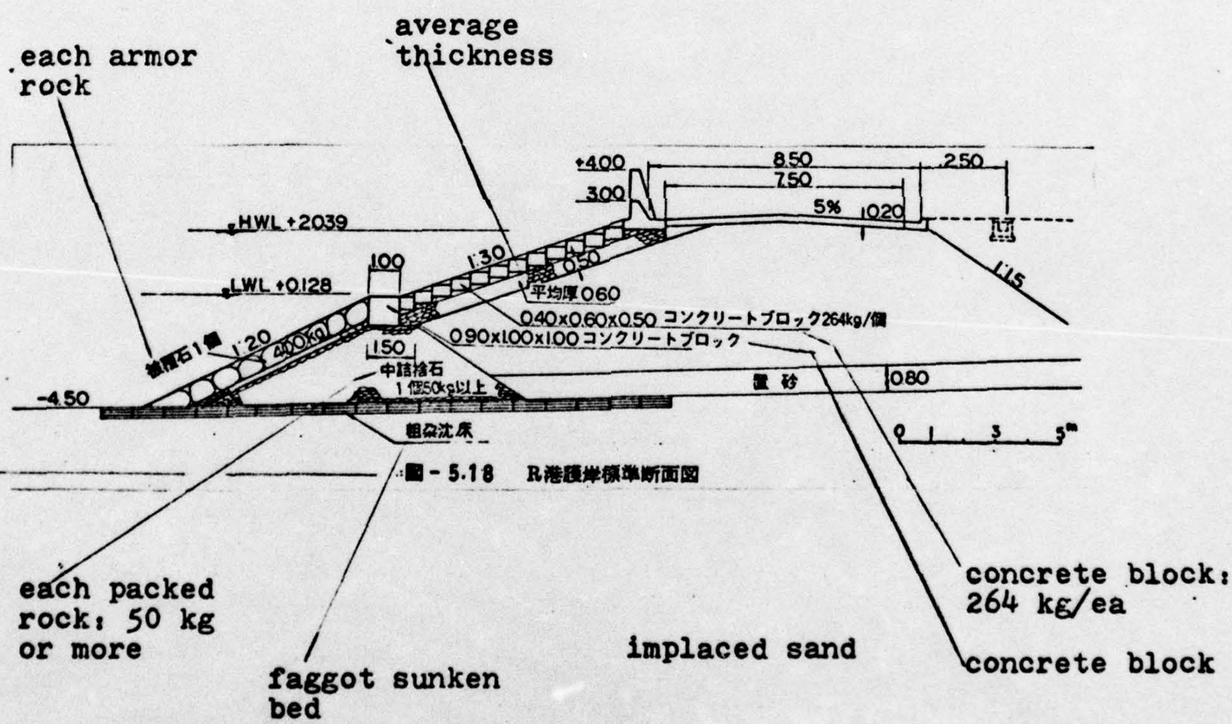


図-5.18 R港護岸標準断面図

Photo 5.74 - General View (for showing the sinking condition)

Photo 5.75 - Angular Break of Parapet (exposure of ferro-concrete)

Photo 5.76 - Concrete Crack of Corner Angle Section

写真 - 5.74
全景（沈下のようすが明らか）

写真 - 5.75
胸壁の目地の角欠け（鉄筋の露出）

写真 - 5.76
隅角部のコンクリートの割れ

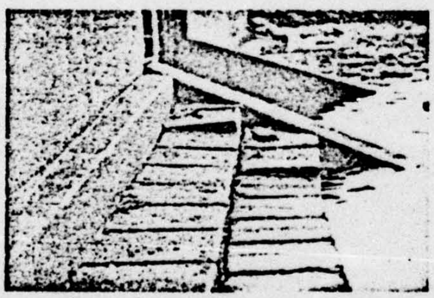


写真 - 5.77　前面の沈下状況

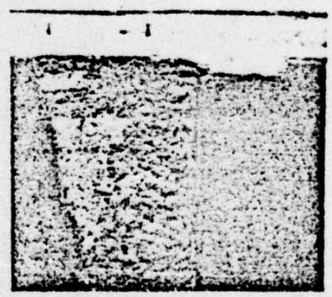


写真 - 5.78　胸壁上端のコンクリートのはがれ

Photo 5.77 - Sinking Condition of the Front

Photo 5.78 - Erosion of Parapet Upper Portion Concrete

19. "S" Harbor: Sea Wall

Sea wall located on the bank of Toyama Wan [Bay] in Noto peninsula and inside an inlet with the mouth facing to the south; not sufficient anti-wave provision provided and thus exposed to relatively constant wave action but from the appearance of the rear condition, the strength intensity of the wave action appears fairly mild; fisheries experiment station and farm homes located to the rear; sea wall, a vertical concrete structure; concrete wall installed on rock foundation, but now showing rupture at connecting points; innumerable cracks in wave deflector; constructed in 1937-1938 and shows poor mixture of concrete; portion of crown shows sinking of about 2 cm as well as cracks in several places.

Chart 5.19 - Standard Cross-section Sketch of "S" Harbor Sea Wall

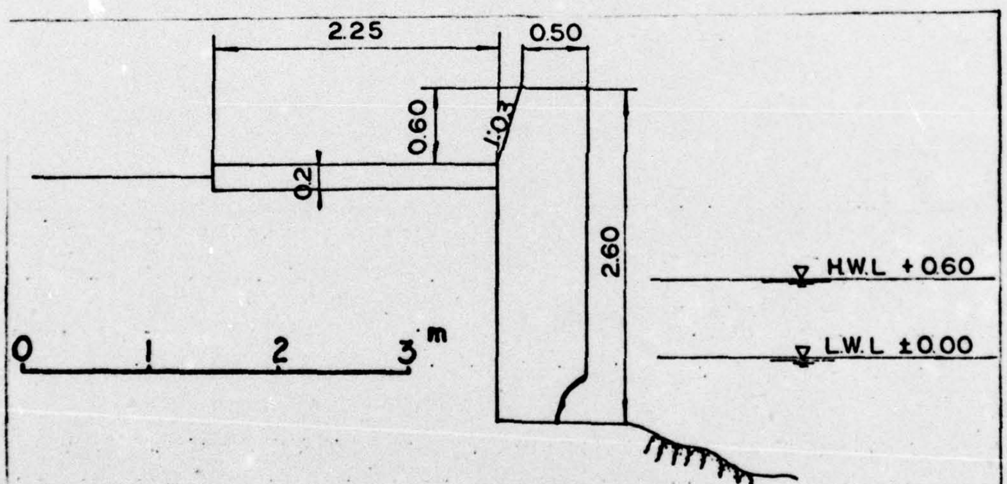


図-5.19 S港護岸標準断面図

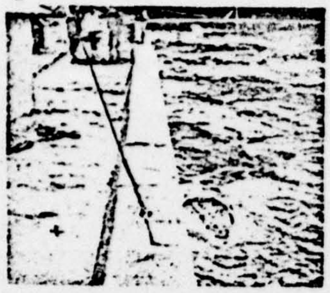


写真-5.79 全景

Photo 5.79 - General View

写真-5.80 波返し工の損傷

Photo 5.80 - Damage to Wave Deflector

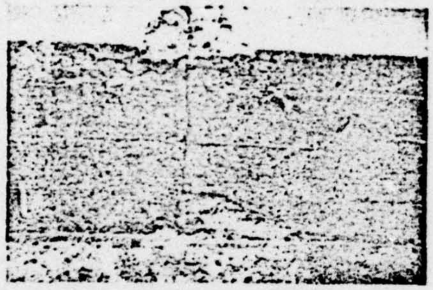


写真-5.81 波返し工目地の損傷，クラック

Photo 5.81 - Damage, Cracks of Wave Deflector Ground Site

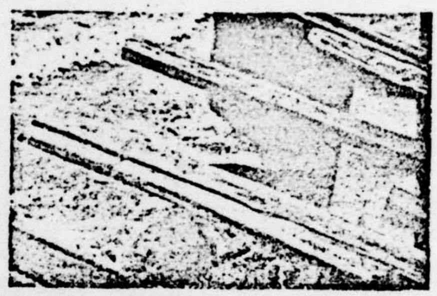


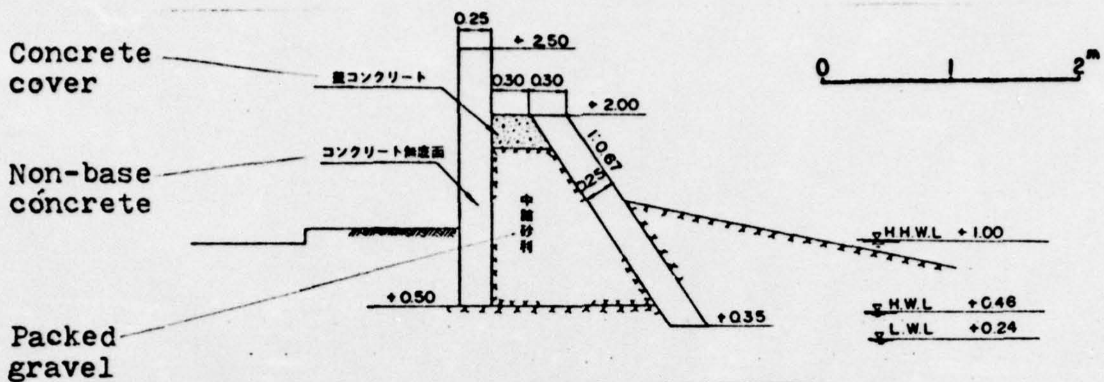
写真-5.82 岩盤との接続部の欠け

Photo 5.82 - Breaks and Erosion of Connecting Part with Rock Foundation

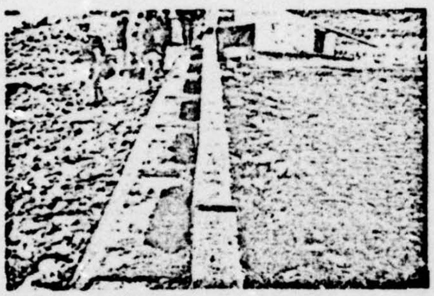
20. "T" Harbor: Sea Wall

Sea wall located near the eastern part of Toyama Wan (bay); believe relatively heavy wave action being encountered; front beach: relatively steep inclined rocky shore; farmland and farm homes located to the rear; known as Saito-type sea wall of non-base concrete constructed in 1958; normal line aberration of about 2.5 cm and a large breach of about 6.5 cm between ground site and adjoining armor; serious abrasion of concrete that shows vertical and horizontal cracks; about 20 cm on both sides, only remaining structures are embankments.

Chart 5.20 - Standard Cross-section Sketch of "T" Harbor Sea Wall

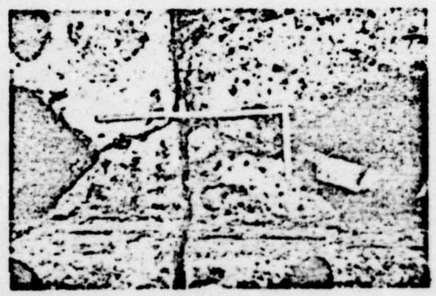


図－5.20 T港護岸標準断面図



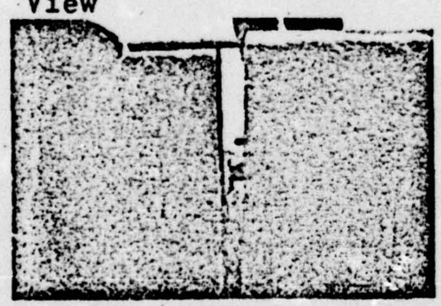
写真－5.83 全景

Photo 5.83 - General View



写真－5.84 表のり工のクラック

Photo 5.84 - Crack of Wave Deflector



写真－5.85 目地のひらき

Photo 5.85 - Breach of Ground Site

写真－5.86 波返し工の摩耗

Photo 5.86 - Abrasion of Wave Deflector

21. "U" Harbor: Sea Wall

Sea wall facing Uchinoumi; believe not encountering any strong wave action; dense farm homes located to the rear; portion of reinforced bedding rocks scattering to endanger foundation by erosion; severe abrasion of lower part of concrete wall as well as extensive damages; normal line water level direction crack and right angle crack showing in concrete wall; crack along 7 cm pitch of wave deflector; 12 cm cave-in of apron to indicate possible erosion of fills; horizontal crack in parapet.

Chart 5.21 - Standard Cross-section Sketch of "U" Harbor Sea Wall

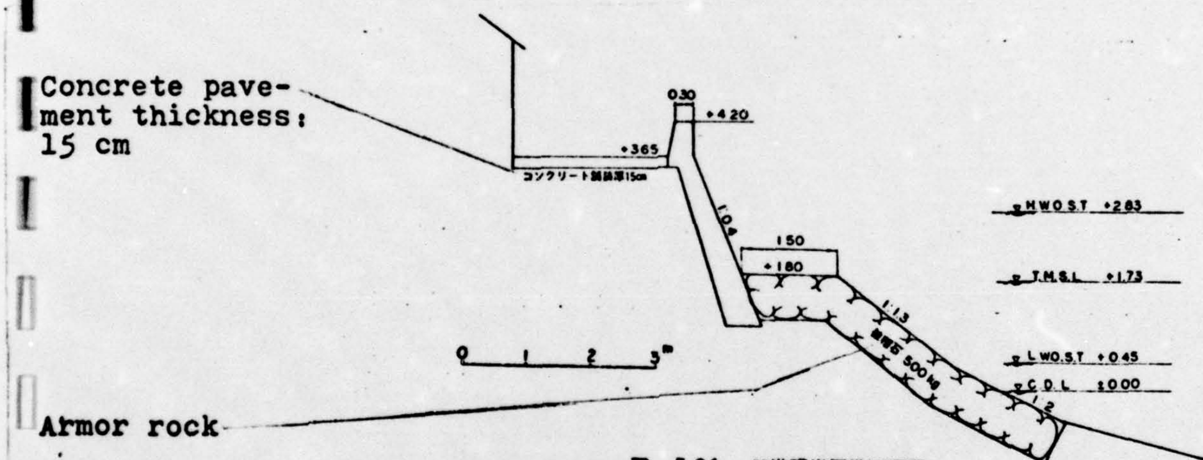


図-5.21 U港護岸標準断面図

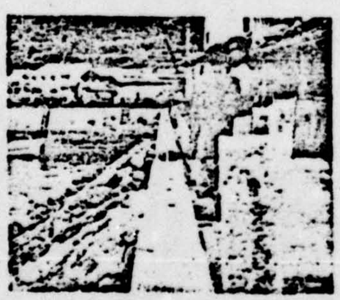
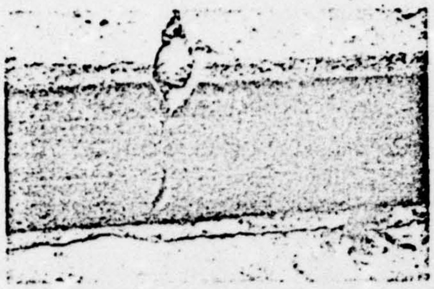


写真-5.87 全景

Photo 5.87 - General View

写真-5.88 表のり工のクラック

Photo 5.88 - Crack of Face Spread



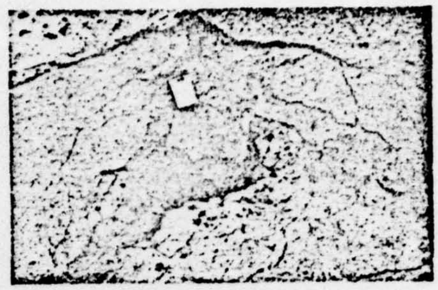


写真 - 5.89 波返し工のクラック，損傷

Photo 5.89 - Crack, Damage of Wave Deflector

写真 - 5.90 水叩工の沈下，損傷

Photo 5.90 - Sinking, Damage of Apron

22. "V" Harbor: Sea Wall

Harbor located in Uchinoumi; believe no action of wave against sea wall; paddy fields located to the rear; about 2 cm wide horizontal crack in mid-section of face spread; throughout the length of wave deflector, crack observed around the mid-section (about 7-8 m) of almost every 15-m block; no covering on aprons but no danger of erosion from overtopping waves and thus, could be left without any change.

Chart 5.22 - Standard Cross-section Sketch of "V" Harbor Sea Wall

newly constructed section

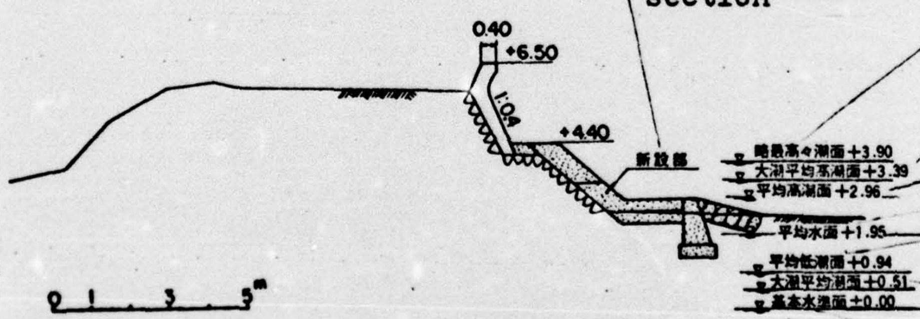


図 - 5.22 V港護岸標準断面図

- "Ryaku" [abridged?] maximum high tide surface
- flood tide mean high tide surface
- mean high tide surface
- mean water surface
- mean low tide surface
- flood tide mean lo tide surface
- basic water level/ standard surface

写真 - 5.91　全景
Photo 5.91 - General View

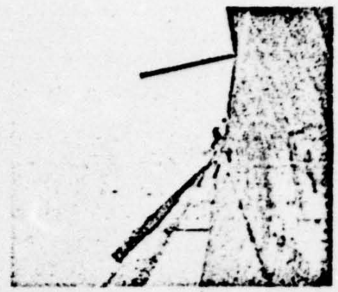


写真 - 5.92　表のり形状（小段部）
Photo 5.92 - Condition of Face Spread (step section)

写真 - 5.93
波返し工の縦方向クラック

写真 - 5.94　表のり工のクラック

写真 - 5.95　波返し工のクラック

Photo 5.93 - Vertical Direction Crack of Wave Deflector

Photo 5.94 - Crack of Face Spread

Photo 5.95 - Crack of Wave Deflector

23. "W" Harbor: Sea Wall

Harbor facing Uchinoumi; sea wall constructed as an aqueduct sea wall between two reclaimed lands and thus, completely free of wave action; thermal power plant, factories, etc., located to the rear; constructed around 1929 and no abrasion observed on parapet due possibly to use of abundant concrete; normal line indentations visible in face spread as well as aberration to the front and back at the ground site, but these believed to be from the time of construction; a number of cracks and angular damage as well as exposure of tidal [river?] section; observed meandering normal line (presumably from the time of construction) and soil erosion of wave deflector; about 4 cm aberration of both front and back of ground site; observed inclined crack of ground site; mixed grass growing on apron; about 50 cm deep, 1 m wide, and 2 m long cave-in in back **part** of parapet indicating erosion of fills.

Chart 5.23 - Standard Cross-section Sketch of "W" Harbor Sea Wall

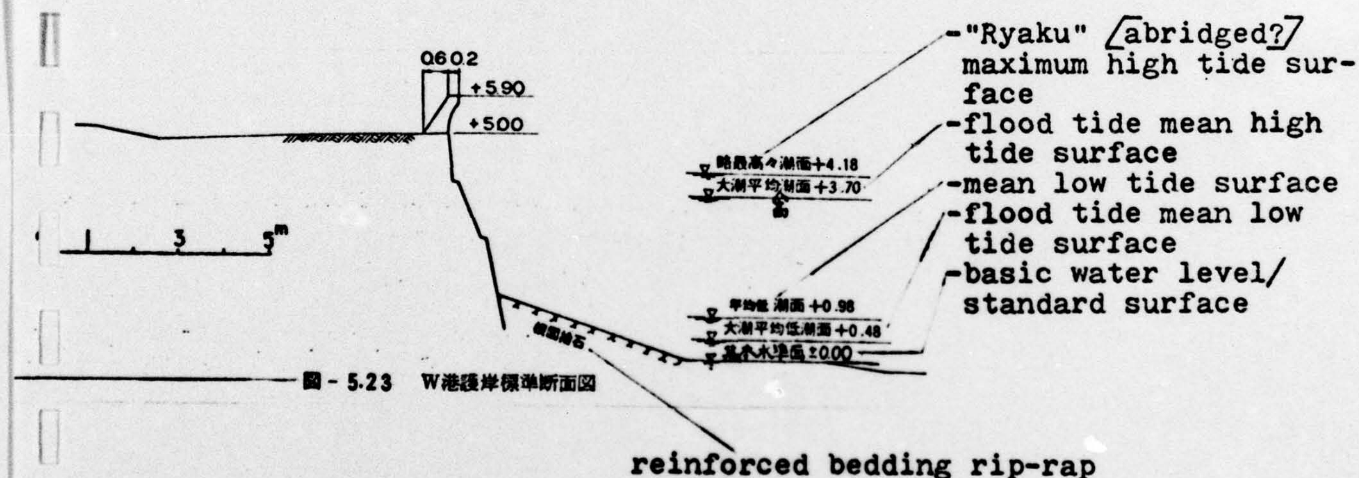


図-5.23 W港護岸標準断面図

Photo 5.96 - General View (showing normal line indentation)

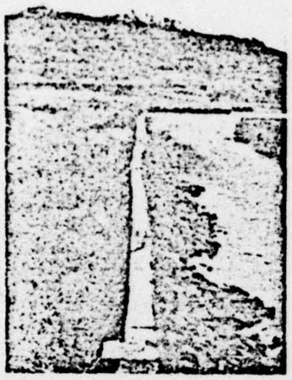


写真-5.96 全景（法線の凸凹）

Photo 5.97 - Removal of Wave Deflector for Repair Work

写真-5.97 改良工事のための波返し工の撤去

Photo 5.98 - Condition of Parapet Concrete Pile Joint

写真-5.98 胸壁コンクリートの打継部の状況

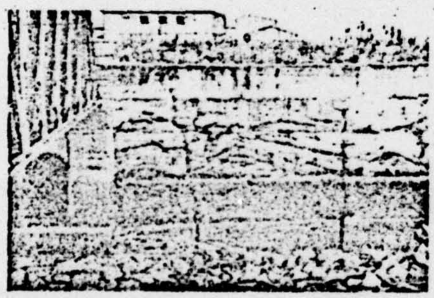


写真-5.99 表のり工のクラック

Photo 5.99 - Cracks of Face Spread

写真-5.100 コンクリート断面（撤去されたコンクリート）

Photo 5.100 - Concrete Cross-Section (Eroded concrete)

24. "X" Harbor: Sea Wall

Sea wall located in a harbor facing a bay that opens to the east /exact location not given/; since the location is a place where the waves converge, this sea wall is believed to be feeling the brunt of various wave actions; dense homes located to the rear; front side constructed of hollow triangular blocks and no change observed in face spread; exposure of ferro-concrete of wave deflector as well as rusting in several places noticed; crack observed in a 10 m block middle section; overall speaking, no sinking of any great degree observed; dissipation work conducted in the front side reduced over-topping waves to make the rear side fairly secure.

Chart 5.24 - Standard Cross-section Sketch of "X" Harbor Sea Wall

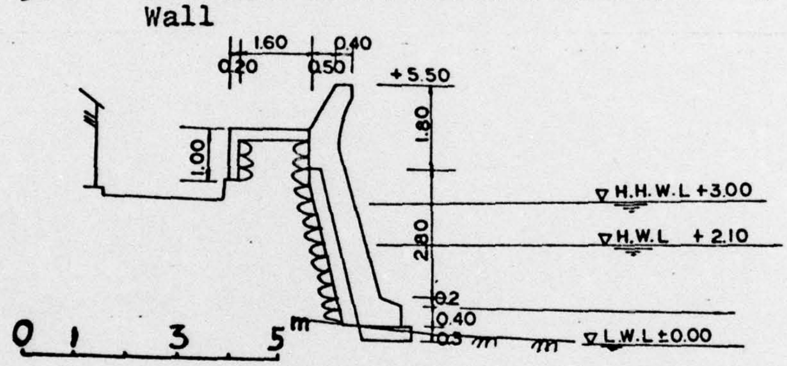


図-5.24 X港護岸標準断面図

写真-5.101 全景

Photo 5.101 - General View

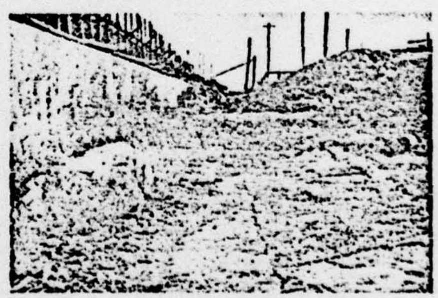


写真-5.102 水叩工の沈下, クラック

Photo 5.102 - Sinking, Cracking of Apron

写真 - 5.103 前面消波工の施工状況

Photo 5.103 - Wave Dissipation Work Scene for the Front Side

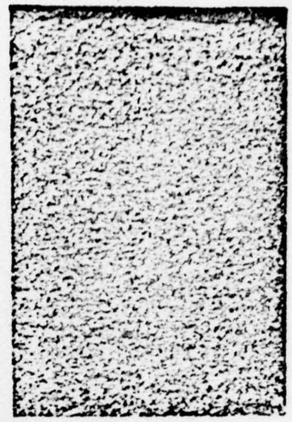


写真 - 5.104 波返し工背面のコンクリートの劣化

Photo 5.104 - Concrete Wasting on the Back Side of Wave Deflector

25. "Y" Harbor: Sea Wall

A reclaimed site sea wall [exact location not given] presumably exposed to strong action of waves; back area of sea wall used as a yard for storage, such as lumber, etc., for harbor and bay; front side constructed of tetra pod covering; a parapet sea wall of relatively high structure; no change observable in face spread; vertical soil erosion of about 8 mm in wave deflector; rusting and efflorescence of ferro-concrete; mid-section crack in 20 m long block; normal line direction water level crack in ground site; apparent apron breach with wave deflector and rear step type sand guard at ground site; normal line right angle direction crack in step section in one place.

Chart 5.25 - Standard Cross-section Sketch of "Y" Harbor Reclaimed Site Sea Wall

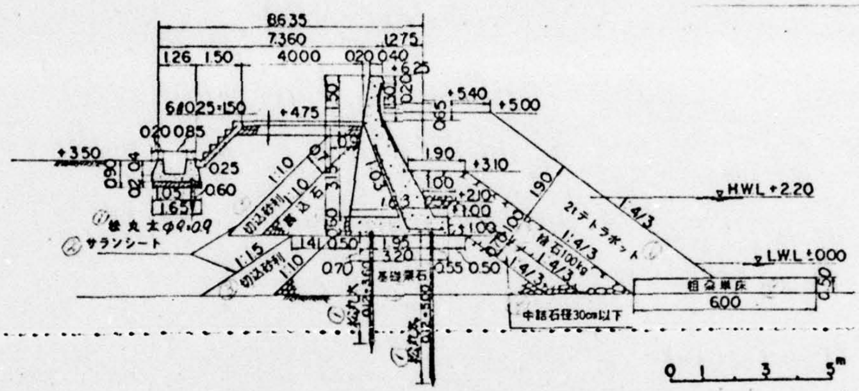


図-5.25 Y港埋立護岸標準断面図

Key:

1. Pine log
2. "SARAN SHITO" [saran sheet?]
3. Unscreened gravel
4. Rock fill
5. Foundation pebble stones
6. Tetra pod
7. Rip-rap
8. Packed rock diameter: 30 cm or less
9. Single faggot bed

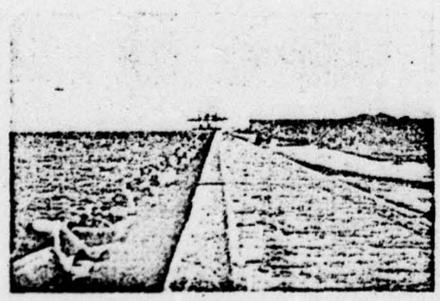


写真-5.105 全景

Photo 5.105 - General View

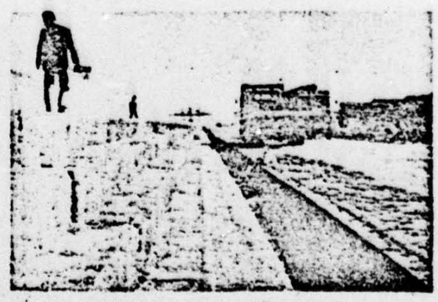
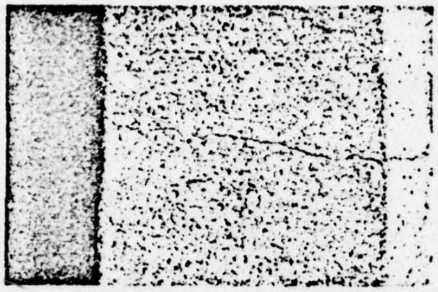


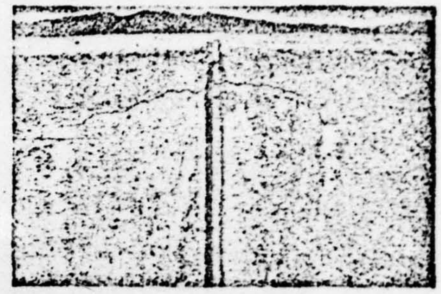
写真-5.106 背面階段部

Photo 5.106 - Rear View of Step Section



写真－5.107 波返し工のクラック（上面）

Photo 5.107 - Crack of Wave Deflector (upper surface)



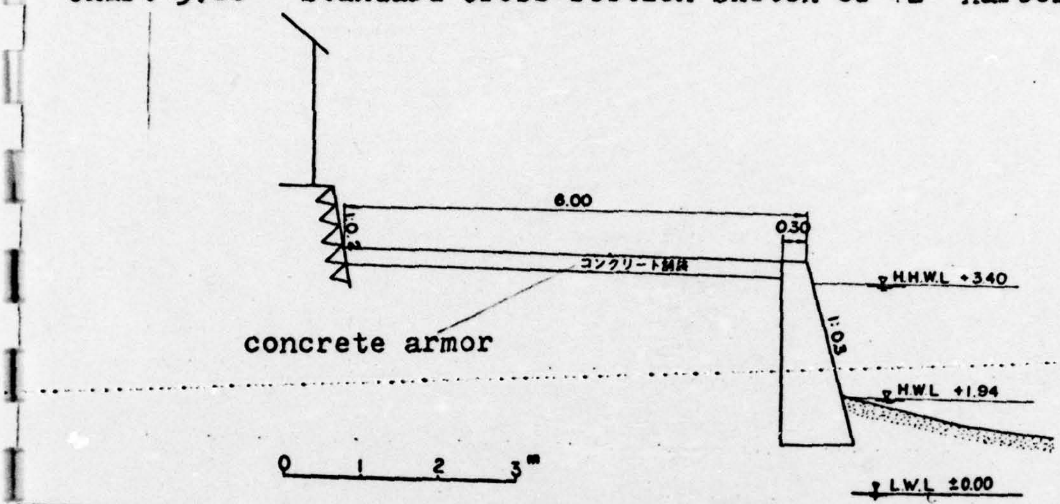
写真－5.108 波返し工のクラック（背面）

Photo 5.108 - Crack of Wave Deflector (back surface)

26. "Z" Harbor: Sea Wall

Sea wall facing bay that opens to the east [exact location not given]; presumably exposed to strong wave action; old coastline extended to the very front of homes, but a road was constructed in front of these homes; this sea wall now serving as the wall for this road, but the waves are still reaching this road because no parapet has been constructed; at the present time, new sea wall is being constructed at this site; severe abrasion of lower part of concrete; exposure of structural parts as well as number of holes; part of the sea wall damaged by calamities already restored; two to three cracks in 8-m long block; holes and water puddles on road surface that shows 3-4 cm sinking; innumerable cracks visible.

Chart 5.26 - Standard Cross-section Sketch of "Z" Harbor Sea Wall



図－5.26　Z港護岸標準断面図

写真－5.109　全景

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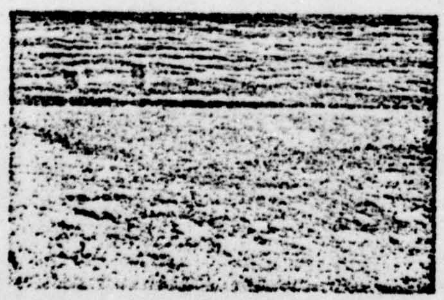
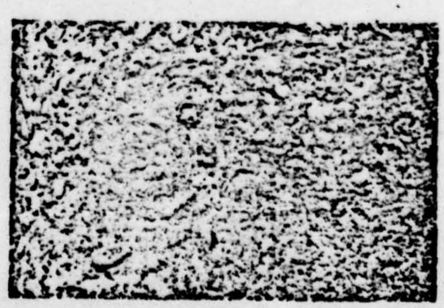
写真－5.110　前面コンクリートの損傷

Photo 5.110 - Damage of Face Concrete



写真－5.111　水叩工（路面）の沈下，損傷による水溜り

Photo 5.111 Sinking of Apron (road surface), Water Puddles from Damages



写真－5.112　コンクリートの摩耗

Photo 5.112 - Abrasion of Concrete

27. "Z-1" Harbor: Sea Wall

Sea wall located in the innermost part of a harbor surrounded by small islands [exact location not given]; presumably not exposed to wave action of outside waters; serving as a road sea wall; not provided with a parapet because of neglible wave action; deep water in front of foundation but no fear of erosion from wave action; crack observed in 20-m long face spread block; normal direction crack in road surface asphalt about 3 m back of the 5 m sunken normal line; sinking of downward slope section, presumably caused by [soil?] erosion of foundation rather than by forward tilting or sliding since no conspicuous normal line change.

Chart 5.27 - Standard Cross-section Sketch of "Z-1" Harbor Sea Wall

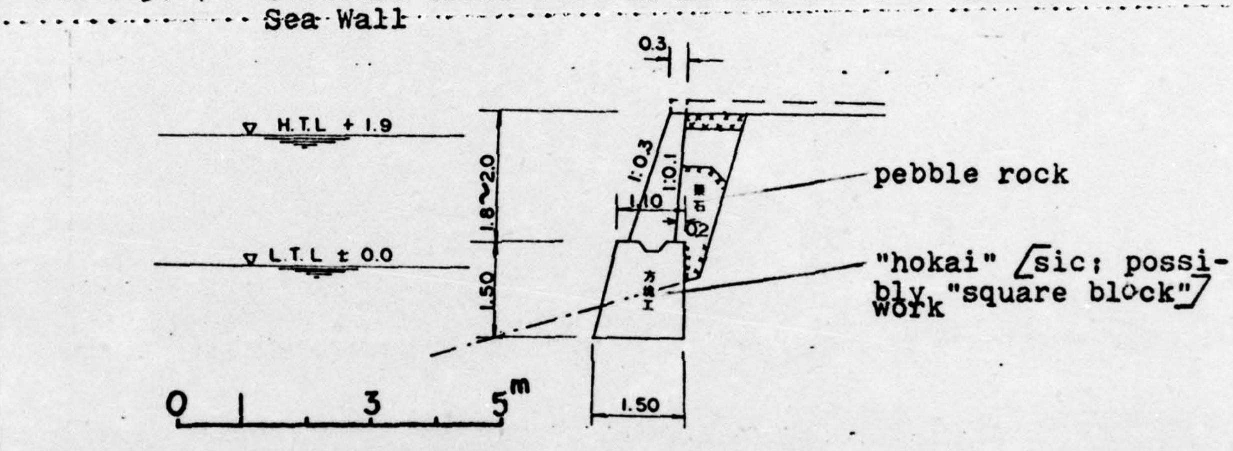


図-5.27 Z-1港護岸標準断面図

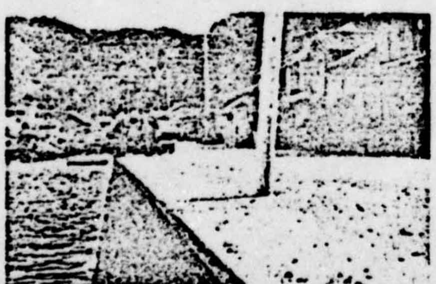


写真-5.113 全景

Photo 5.113 - General View

写真-5.114 水叩工の沈下

Photo 5.114 - Sinking of Apron

写真-5.115
水叩工（路面）のクラック（法線方向）

Photo 5.115 - Crack of Apron (road surface)(normal line)

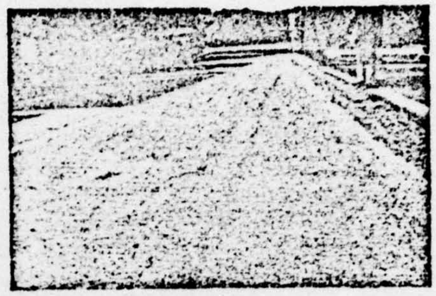


写真-5.116 水叩工（路面）のクラック

Photo 5.116 - Crack of Apron (road surface)

28. "Z-2" Harbor: Sea Wall

A vanguard sea wall constructed on a reclaimed land [exact position not given]; presumably exposed to action of waves because of its location; area in the rear: factory site; scattering of reinforced bedding rocks and serious abrasion of lower part concrete of face surface; holes and ruptures in face surface; big crack in foundation concrete; 5-8 mm aberration to both front and back of wave deflector; crack in 12-m long block near 3-5 m pitch; sinking of apron to develop water puddles and 20 cm cave-in section causing erosion of fills; breach, angular break, and innumerable cracks in ground site.

Chart 5.28 - Standard Cross-section Sketch of "Z-2" Harbor Sea Wall

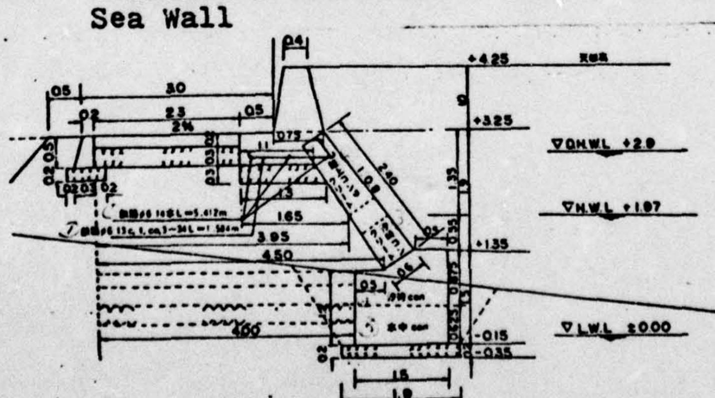


図-5.28 Z-2港護岸標準断面図

Key:

1. Ferro-concrete
2. Shore/above ground concrete
3. Tidal hour concrete
4. Waiting-for-the-tide concrete
5. Underwater

写真-5.117 全景

o 5.117
neral

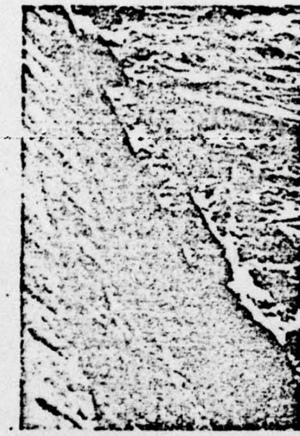


写真-5.118
前面根固部コンクリートの破壊

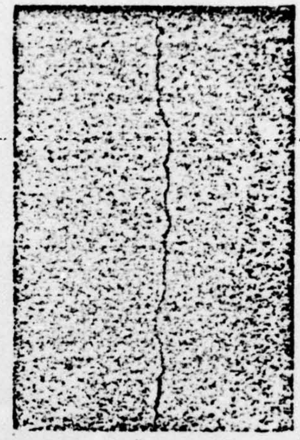


写真-5.119 波返し工のクラック

Photo 5.119-Crack of Wave Deflector

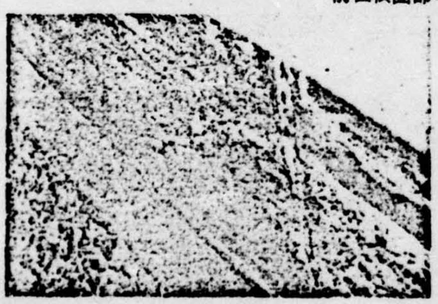


写真-5.120 前面コンクリートのクラック

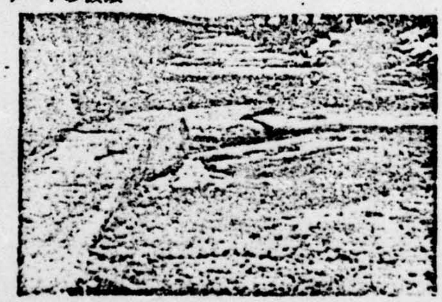


写真-5.121 裏込の吸出しによる水叩工の陥没

Photo 5.120 - Cracking of Face Concrete

Photo 5.118 - Destruction of Front Reinforced Bedding Concrete

Photo 5.121 - Apron Cave-in From Erosion of Fills

Table - 5.2 (1)

表-5.2(1)

護岸(石積)① 護岸(石積)②

③ 工種	④ 外観の状況 / 個所 ⑤ ⑥	A	B	C	D	E	F	G	H
基礎工	石積との連結部の状況 ⑦								
	胴詰め石の状態 ⑧	変化なし ⑪	〃	変化なし ⑪					一部脱落 ⑭
	基部ブロックの状態 ⑨	〃		〃			変化なし ⑪		
	其他 ⑩	なし ⑫	なし ⑫	〃	なし ⑫	なし ⑫	目地の開きあり ⑬	なし ⑫	なし ⑫
⑮ 護岸のり面部	目地部分のはらみ出し ⑯	なし 〃	なし 〃	なし ⑫	目地石開き ⑲ 一部ふくらみあり ⑳	なし 〃	なし ⑫	なし 〃	なし 〃
	〃 はらみ出し ⑰	〃	〃	〃	なし ⑫	〃	〃	〃	〃
	〃 へこみ ⑱	〃	〃	〃	あり ㉑	〃	〃	〃	〃
	材料 角欠け ㉒	なし 〃	〃 〃	〃	なし ⑫	〃 〃	〃	あり ㉑	なし 〃
	摩耗 ㉓	〃	〃	表層部摩耗大 ㉖	〃	少々あり ㉗	〃	磨耗大、骨材露出 ㉘	〃
	破損 ㉔	〃	〃	なし ⑫	〃	なし ⑫	〃	なし ⑫	〃
	表面の汚さ状況 ㉕								
	目地部の状況 ㉙			目地コンクリートのはくりあり ㉝	目地コンクリートはくり目地上 [illegible] ㉞	〃			目地コンクリートはくり(下部) ㉟
	角欠け ㉚					〃			[illegible] ㊱
	上下ずれ ㉛					〃			[illegible] ㊲
	前向ずれ ㉜					〃			[illegible] ㊳ ㊴
	[illegible] ㊵		[illegible]			[illegible] ㊷			
	角欠け								
	上下ずれ					なし ⑫			
	前向ずれ								
	[illegible]								
	角欠け								
	上下ずれ								
	[illegible]	なし ⑫	なし ⑫		なし ⑫	なし ⑫	[illegible]		[illegible]
	角欠け	〃	〃		〃	〃	なし ⑫		なし ⑫
	ずれ	〃	〃		〃	〃			
	[illegible]			[illegible] ㊾		〃	[illegible]	なし ⑫	
	[illegible]					一部あり ㊿	㊿		[illegible]
[illegible]	[illegible]	なし ⑫	なし ⑫		なし ⑫	なし ⑫	なし ⑫	なし ⑫	[illegible]
	不陸		〃			〃			あり
	材料 角欠け	[illegible]			[illegible]	〃	〃		[illegible]
	摩耗	[illegible]	[illegible]			〃	〃		摩耗大
	破損	なし ⑫	なし ⑫		摩耗あり	〃	〃	なし ⑫	[illegible]
	[illegible]	[illegible]	なし ⑫		なし ⑫	[illegible]	なし	なし ⑫	なし ⑫
	[illegible]	〃	〃			〃	〃	[illegible]	〃
	上下ずれ	〃	〃			〃	〃	なし ⑫	〃
	前向ずれ	〃	〃			〃	〃		〃
	[illegible]	[illegible]	[illegible]		[illegible]	なし ⑫	〃	[illegible]	〃
	[illegible]	なし ⑫			なし ⑫	[illegible]		なし ⑫	
㊵ [illegible]	不陸	なし	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	へこみあり [illegible]
	材料 角欠け	[illegible]	[illegible]	なし ⑫		[illegible]			
	摩耗	なし ⑫	〃	〃		なし ⑫			摩耗大 [illegible]
	破損	なし ⑫	〃			[illegible]			
	[illegible]	なし ⑫	〃			[illegible]			
	角欠け	〃	〃			〃			
	上下ずれ	〃	〃			〃			
	前向ずれ	〃	〃			〃			
	[illegible]	〃	〃			〃			[illegible]
	角欠け	〃	〃			〃			あり
	上下ずれ	〃	〃			〃			なし ⑫
	[illegible]	〃	〃			〃			
	角欠け	〃	〃						
	上下ずれ	〃	〃						
	[illegible]		〃	[illegible]		あり			[illegible]
	[illegible]	[illegible]				〃			なし ⑫
[illegible]	[illegible]	なし ⑫	[illegible]	〃	[illegible]				
	[illegible]	〃		〃					
	へこみ	〃		〃					
	[illegible]	〃		〃					
	材料 角欠け	〃		〃					
	摩耗	〃		〃					
	破損	〃		〃					
	[illegible]	〃							
	[illegible]	〃			〃				
	角欠け	〃							
	上下ずれ	〃							
	[illegible]	なし ⑫							
	[illegible]	〃							
	角欠け	〃							
	上下ずれ	〃							
	前向ずれ	〃							
	[illegible]	[illegible]							
	角欠け								
	上下ずれ								
	[illegible]	なし ⑫			なし				
	[illegible]								

Table - 5.2 (2)

表-5.2(2)

[illegible] 物(コンクリート)(116)

	I	J	K	L	M	N	O	P	Q
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table - 5.2 (3)

表-5.2(3)

[illegible] (コンクリート) (174)

工種 (3)	(4) 変状の状況 / [illegible] (16)	R	S	T	U	V	W	X	Y	Z	Z - 1	Z - 2
[illegible] (6)	[illegible] (1) [illegible] (5) [illegible] (7) [illegible] (10)	なし (12)	[illegible] (152)	なし (12)	(181) [illegible] [illegible] (131)	なし (12)	(11) 変化なし / なし (12)	(151) [illegible]	(11) 変化なし	(12) なし	(184) [illegible]	(183) [illegible] (12) なし
	[illegible] (16) / [illegible] (17) / [illegible] (18)	[illegible] (186)			なし	なし	[illegible] (157) / なし (12)	(12) なし	(12) なし	(12) なし	[illegible] / なし (12)	なし (12)
(15)	[illegible]	なし (12) [illegible]			[illegible]		[illegible] (21)			[illegible]		[illegible]
	[illegible]	[illegible]					[illegible]			[illegible] (12)		[illegible]
	[illegible]	[illegible]					[illegible] (196)					
	[illegible] (67)	[illegible]										[illegible]
	[illegible]	[illegible] (12)				なし (12)	なし (12)	なし (12)				
	[illegible]	なし (12)		[illegible]	[illegible] (194)		[illegible] (21)		[illegible]	[illegible] (200)	[illegible] (201)	[illegible]
(50)	[illegible] (52)	[illegible] (204)	[illegible] (206)	[illegible] (207)	なし (12)	なし (12)	[illegible] (208)	なし (12)	なし (12)			[illegible] (12)
	[illegible]	[illegible]	[illegible]	[illegible]	なし (12)	なし (12)	なし (12)	なし (12)	なし (12)			なし
	[illegible]	なし	なし (12)	なし (12)	なし (12)	なし (12)	なし (12)	[illegible] (214)	[illegible] (213)			[illegible] (21)
	[illegible]	[illegible] (21)	[illegible] (12)	[illegible]		なし (12)	なし (12)	なし (12)	[illegible] (12)			[illegible] (12)
	[illegible]	[illegible] (214)	[illegible] (215)	[illegible]	[illegible] (216)	[illegible]	[illegible] (219)	[illegible]	[illegible]			[illegible]
	[illegible]					なし (12)	なし (12)	なし (12)	[illegible]			(12)
	[illegible] (55)	[illegible] (222)	[illegible] (223)		[illegible] (224)	[illegible] (226)	[illegible] (227)		[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]		[illegible] (12)		なし (12)				なし (12)	[illegible]	[illegible]	[illegible] (12)
	[illegible]		[illegible] (12)		[illegible] (12)				[illegible] (12)	[illegible] (12)		[illegible] (12)
	[illegible]		[illegible]		[illegible]				[illegible] (12)	[illegible] (21)		[illegible] (12)
	[illegible]								[illegible]			
	[illegible] (185)		[illegible] (234)		なし (12)				[illegible] (12)	[illegible] (236)		[illegible] (237)

Key for Tables 5.2 (1)(2)(3):

1. Embankment (masonry)
2. Sea Wall (masonry)
3. Type of Structure
4. Visible External Condition
5. Name/Symbol of Harbor
6. Foundation
7. Joint/Connection condition with rock foundation
8. Condition of reinforced bedding covered rocks
9. Condition of wave dissipation block
10. Erosion
11. No change
12. None
13. Shifting of pebble rocks
14. Partial shifting
15. Face Spread Armor
16. Exposure of normal line right angle direction
17. Cracking of normal line right angle direction
18. Cave-in of normal line right angle direction
19. "Kanchi" masonry
20. Partial bulging
21. Occurence observed
22. Angular break of material
23. Abrasion
24. Damage
25. Surface rusting
26. Abrasion great for tidal section
27. Some observed
28. Abrasion great, exposure of structural materials
29. Vertical breach of ground site
30. Angular break
31. Vertical aberration
32. Aberration inside surface
33. Exfoliation of manually packed concrete
34. Exfoliation of manually packed concrete and subsequent drainage into the sea from ground site
35. Exfoliation of manually packed concrete (lower part)
36. For two places/positions
37. "Kanchi" rocks, one or two places
38. Some drainage observed
39. Probable existence of air/weep holes
40. Horizontal break of ground site
41. Extended horizontal opening in lower section (sinking)
42. Damage to pile joint of concrete and "Kanchi" block
43. Break between foundation and pile joint
44. Break between parapet and pile joint
45. About 2 cm water level break due to sinking of masonry section
46. Existence of opening
47. Normal line direction crack
48. Normal line right angle direction crack
49. Crack at ground site
50. Exists for one section
51. Water level crack
52. Wave reflector
53. Normal line indentation
54. Soil erosion
55. Bending (from the time of construction)
56. Angular break of material
57. Abrasion of material
58. Damage of material
59. Perimeter crack
60. Poor mixing
61. Forward tilting
62. Break/crack
63. Abrasion observed
64. Depth: 11 cm
65. Abrasion great
66. Exposure of structural materials
67. Surface rusting of materials
68. Efflorescence
69. Existence of efflorescence

(Continued Key for Tables - 5.2 (1)(2)(3))

70. Break at Ground Site
71. Vertical aberration of ground site
72. Front and back aberration of ground site
73. Normal line right angle direction crack
74. Normal line right angle direction water level crack
75. Hair crack every 3-5 m
76. 10 m pitch
77. Crack at one place
78. 5 m pitch
79. Observed in pile joint
80. Crown
81. Employed as road; 7 cm sinking of asphalt covering
82. Drainage of rocks observed
83. Mixed grass
84. 4 cm sinking
85. Road [condition?] unknown
86. Road asphalt covering
87. Observed cave-in(s) and unevenness
88. Crack, perimeter break
89. Unknown
90. Observed in corner angle section
91. Abrasion great; cave-in(s) observed
92. Break at work site
93. Angular break at work site
94. Vertical break at work site
95. Aberration inside surface at work site
96. Unknown if earth and sand were eroded
97. Breach between wave deflector and ground site
98. Angular break of wave deflector
99. Vertical aberration of wave deflector
100. Breach with rear spread at the ground site
101. Erosion behind parapet
102. Angular break of rear spread
103. Vertical aberration of rear spread
104. Normal line direction crack
105. Normal line right angle direction crack
106. Per 3-5 m; span 10 m too long
107. Large crack observed in 3 places on total length of 230 m
108. Unknown because covered by earth and sand
109. Normal line right angle direction exposure
110. Crack exposure
111. Cave-in
112. Rear spread armor
113. Abundant growth of mixed grass
114. Soil erosion of shoulder
115. Breach with pile joint of bedding anchor
116. Embankment (concrete)

116a. Name (Symbol) of Harbor and District

117. Partial forward tilting
118. Front aberration of bedding anchor

118a. Sinking observed

119. Corner angle section sinking; forward tilting, 2-3 cm
120. Great
121. Observed in edge/border section
122. Poorly mixed structural maerial exposure of 40-m long reinforced bedding

(Continued Key for Tables 5.2 (1)(2)(3))

123: Exposure of structural materials of lower part
124. Depth 30 cm (80 cm x 40 cm)
125. Depth of reinforced bedding concrete: 50 cm (2.5 x 0.5cm)
126. Part of poorly mixed structural materials exposed
127. Observed a very small break
128. Observed a spot that appears to be a break
129. Break
130. Observed at the mid-section (about 5 m) of the 10-m span (total of 3 spans)
131. Large crack observed
132. Observed in 3-5 m pitch
133. Observed at a spot 20 m of 2 spans and 2 m below the upper section
134. Observed in 5 m pitch
135. Observed in the reinforced bedding section
136. Caused level difference in corner angle section
137. Many in corner angle section reinforced bedding
138. Large crack in corner angle section
139. Crack in reinforced bedding concrete
140. Crack
141. Observed in a section of corner angle
142. From the time of construction
143. Uneven sinking
144. 0.5 cm sinking
145. 1 cm sinking and aberration
146. One section tattered due to poor mixing
147. Observed a 1.5 cm fissure that appeared to be a break
148. Observed one spot that appeared to be a break
149. Observed in corner angle section; aberration about 2 cm
150. Observed in the 5 m pitch
151. Located near mid-section (4-5 m) of block
152. Incline crack
153. Observed in corner angle section
154. Observed a single crack in corner angle section
155. 2-3 cm sinking (in 20 m area)
156. 1-2 cm sinking
157. 0.5-1 cm sinking
158. Sinking on sea side great
159. Observed sinking of block covering (due to vehicle traffic)
160. Observed sinking of block covering (due to vehicle traffic)
161. Sinking due to dump /truck?/ traffic (20 cm)
162. Abrasion great
163. Some degree of abrasion
164. Crack due to vehicle traffic
165. Very severe block crack
166. Observed large crack
167. Found in almost all spans
168. Observed one in a 10 m span
169. Observed in 2-3 m pitch
170. Rather than a crown hole, appears to be air/weep hole
170a. ground site
170b. wave deflector
171. Observed =20 cm in the sluice section
172. Exposure from the time of construction
173. Part of block covering exposed (from the time of construction)
173a. Cave-in (from the time of construction)
174. Wasting
175. Small installed sheet
176. Observed in a 10-m span (very long span)

(Continued Key to Tables 5.2 (1)(2)(3))

177. Observed in 3-5 m pitch
178. Observed 10 m pitch below crown
179. Sea Wall (Concrete)
180. Breach from erosion
181. Partial scattering
182. Insufficient depth of anchor
183. Construction of "kuchu sankaku" /literally, "air/aerial triangle/three cornor"/ structure underway
184. Deep sea located in the front, but no fear of bedding erosion
185. Scattering/dispersion
186. 0.5 /cm?/ sinking
187. Meandering (from the time of construction)
188. Estimating from the rear sinking, part of the exposure presumably existed from the time of construction
189. Some degree of abrasion
190. Lower part abrasion great
191. Found in lower part.
192. Exposure of structural materials
193. Severe lower part abrasion and development of exposure hole of structural materials; new construction work underway to restore part of damaged sections.
194. Reinforced bedding section abrasion great
195. In disorder since the time of construction
196. Aberration in front and rear (from the time of construction)
197. Large water level crack
198. Large crack
199. Large 2 cm crack in middle step section
200. Observed in 2-3 places in 8 m block
201. Observed one place in 20 m block
202. Flat surface break: 5 cm
203. Front surface
204. 3 cm forward tilting
205. Observed uneven sinking
206. Bending (from the time of construction)
207. 2.5 cm aberration
208. Meandering (from the time of construction)
209. Sinking
210. Tidal section abrasion, great.
211. Abrasion great.
212. Exposure and ferro-concrete rusting
213. Ferro-concrete rusting and efflorescence
214. Big crack near conveyor and foundation
215. A number of vertical and horizontal cracks
217. Located near the mid-section (7-8 m) of a 15 m block
218. Back surface
219. Crack located mid-section of a 10-m block
220. Crack located mid-section of a 20-m block
221. Crack located in 3-5 cm pitch of a 12-m block
222. Road (asphalt sinking)
223. 1-2 cm sinking
224. 12 cm cave-in
225. No covering
226. No covering; mixed grass
228. Road
229. Concrete covering: holes, water puddles, and 3-4 cm sinking
227. Observed cave-in(s)

(Continued Key to Tables 5.2 (1)(2)(3))

230. Asphalt road
231. Normal line direction crack located 3 m back of normal line; sinking of descending slope on sea side
232. Sinking and water puddles; one section with 20 cm cave-in; erosion
233. Observed what appeared to be a break.
234. Observed one in a block
235. Observed two cracks in a block
236. Observed many cracks
237. A number found in a section

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APPARENT WASTING INDEX OF EMBANKMENTS.(U)
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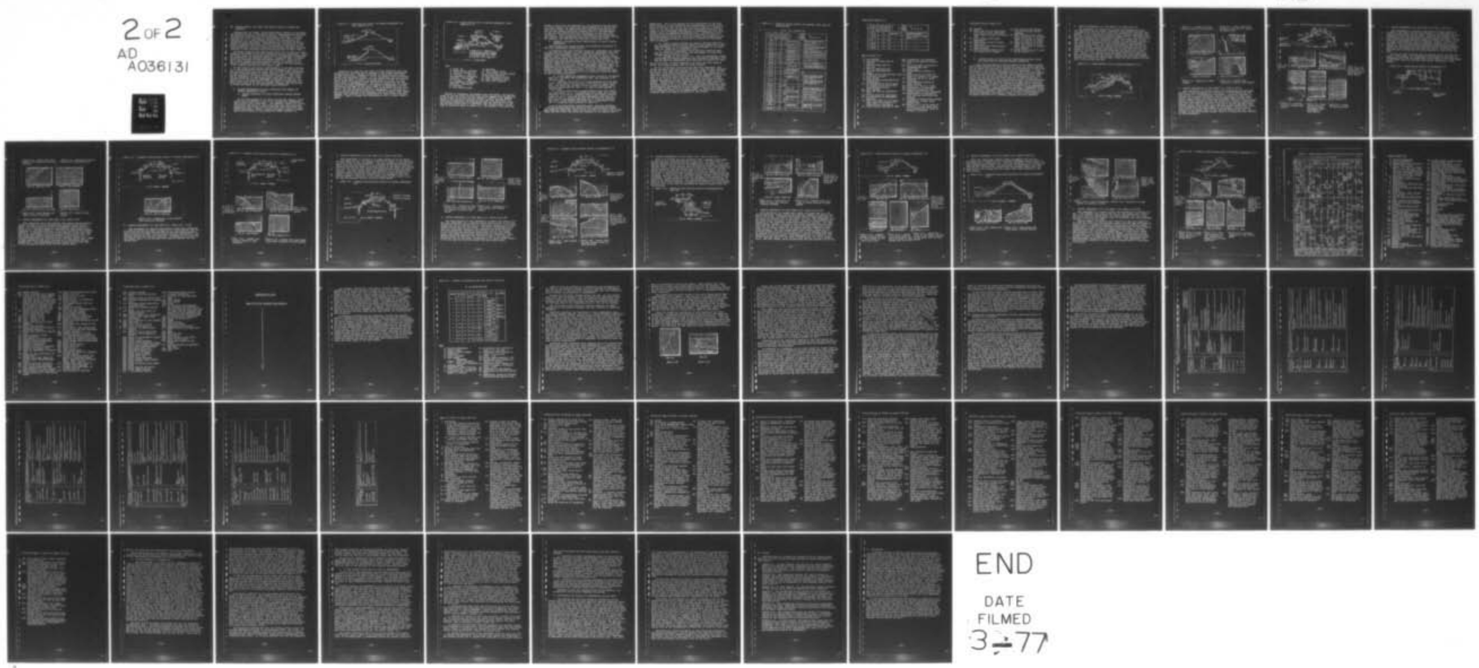

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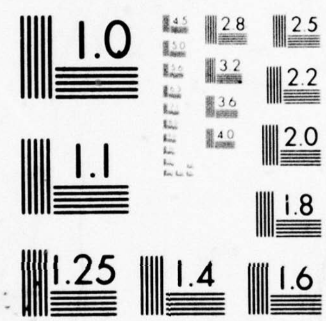


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

VI. Air/Weep Holes, Air Gaps, and Wasting Signs of Coastal Embankments

Changes such as cracks, ground aberrations, wasting of materials and structures, etc., that can be seen on embankments and sea walls are definite indicators of their wastings. Conversely, if these wastings are to be utilized as the indicators of their ultimate destruction (i.e., how strongly possible the destruction), how effectively and efficiently these changes are evaluated becomes a matter of great importance. Needless to say, the reliance on personnel experience and intuition to perform this task would be far from sufficient; it must be based on careful and thorough study and analysis of past disasters and practical testings of model cases.

To better elaborate the points made above, let us take up a hypothetical case where a weep hole develops inside an embankment. Weep/air holes (also air gaps) are major causes of embankment breakdowns as discussed in the previous sections. A question sure to surface after the detection of this development would be: "Which one of the visible changes that had occurred should be employed as the basis to diagnose this development?" The answer to this question is not readily available at the present time.

In the study to gain better understanding of the above problem, i.e., the relationship between the visible changes that occur and the air/weep holes (also air gaps) that develop within embankments, we were fortunate enough to obtain access to the Air/Weep Holes Survey Results of the Aichi Prefectural Government. This report was an attachment to the Survey Report that was prepared in conjunction with the coastal embankment investigation that was conducted over a two-year period (1969 and 1970) to commemorate the 10th anniversary of the Ise Wan typhoon disaster. The discussions to follow are based on the aforementioned attachment.

A. Coastal Embankments of Aichi Prefecture and Summary of Coastal Embankment Survey

a. General Condition of Aichi Prefecture Coastal Embankments

At the time Typhoon No 13 (1953) and Ise Wan typhoon (1959) struck Aichi prefecture, most of the prefectural embankments were solidly built structures. For examples, almost all crowns stood more than T.P.5 m, most structures were wide dimension structures, and almost all were provided with three-side reinforced coverings. Chart 6.1 shows the type of coastal embankments that existed in this prefecture before Typhoon 13.

Chart 6.1 - Cross-section Sketch of Coastal Embankment Before Typhoon No 13

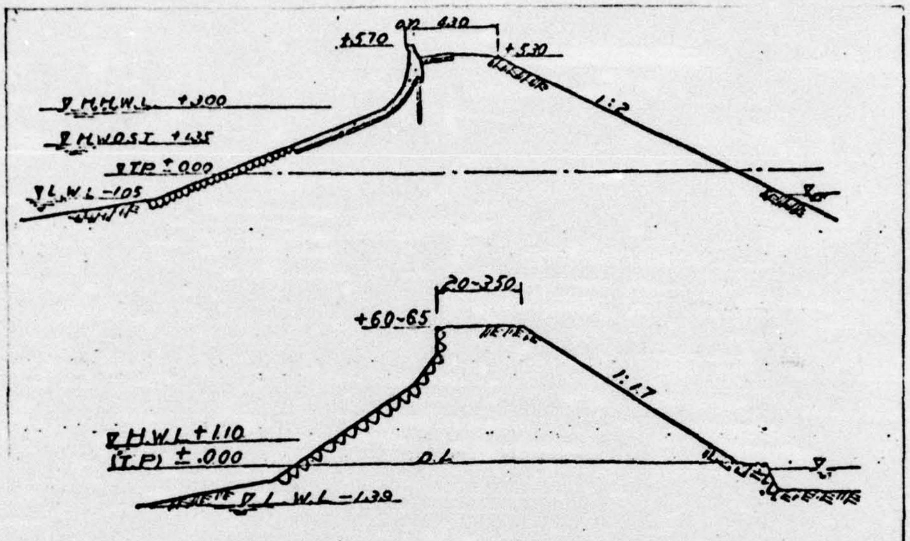


図-6.1 13号台風以前の海岸堤防の断面

Typhoon No 13 that hit the coast of Aichi Prefecture not only destroyed but inflicted severe damages to the coastal embankments of many localities. Damages sustained in Mikawa Wan [bay; same below] were especially severe. In the restoration work undertaken, due care was given to protect the rear spread from the overtopping waves, waves that can erode the spread armor to cause, in turn, the erosion of embankment earth and sand to bring about the toppling of the whole embankment. The measure adopted was to install reinforced coverings to the three sides of an embankment. By the time of the Ise Wan typhoon strike, the installation of this covering to the face spread of almost all embankments in Koromoga Ura Wan and Mikawa Wan had been completed, and as a result, only slight damages were suffered by the embankments in these areas from this typhoon. Chart 6.2 shows the cross-section view of these embankments.

Chart 6.2 - Cross-section View of Coastal Embankment After Typhoon No 13

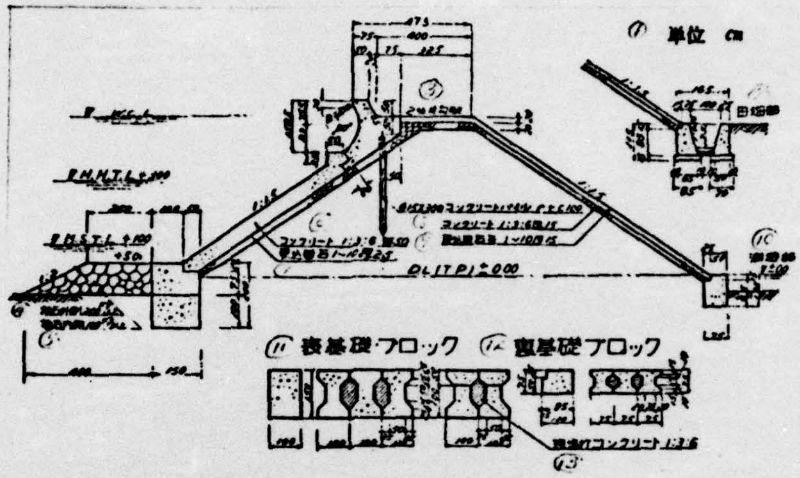


図-6.2 13号台風後の海岸堤防

Key:

1. Unit: cm
2. Paddy field, farmland
3. One-sided slope: 2%
4. Rip-rap, ... /one of two characters illegible; possibly, "exterior"/
5. Rip-rap, ... /one of two characters illegible; possibly, "interior"/
6. Concrete
7. Fill pebble rocks
8. Concrete
9. Fill pebble rocks
10. "shio asobi bu" /literally "tidal play section"/
11. Face foundation block
12. Rear foundation block
13. Spot pile concrete

Because of inadequate improvement work undertaken, the coastal areas of Ise Wan which suffered only slight damage under Typhoon No 13 were hard hit by the Ise Wan typhoon. Almost all the embankments on the northern coastline of this bay were destroyed. The structural restoration of embankments that was carried out in the Ise Wan area after this hit conformed, for the most part, to the type of structure given in Chart 6.2. The height of the crown was

raised a little and the dimension of the structures was enlarged a little, however, to permit the whole embankment to better cope with flood tides. The renovation work that was conducted after the Ise Wan typhoon basically converted most of the embankments in the Ise Wan coastal area into relatively new sea wall type structures. Most of the coastal embankments in the Mikawa area are vertical type embankments that were constructed before the Ise Wan typhoon, but some have been renovated since that time.

1. Summary of Weep/Air Holes Survey Report on Aichi Coastal Embankments

The following are excerpts from the referenced attachment of the Aichi Prefectural Survey Report.

"A weep/air hole that develops inside an embankment but cannot be seen from the surface is a very dangerous development from the standpoint of embankment safety. This can develop into a very serious 'point' and thus, the decision was made to conduct embankment inspection along the whole coastline of the prefecture. After examining the various inspection methods that were available, the primary inspection method selected was the one calling for the digging of a hole (0.5m x 1.0m) through the normal concrete layer to directly check the condition of the embankment earth and sand, supplemented by the method of using a 'sono-timer' /sonometer?/, without removing the concrete armor, to check the diffusion time of elastic wave. The selection of the inspection sites was based on the following principles:

a. A site where the embankment cross section is an embankment type and where the foundation base was adjudged to be soft and weak.

b. Although the cross section may possibly be a sea wall type, a site where the rear area is occupied by homes, road, etc., and where the 'economic effectiveness is great' /not further elaborated/ and thus, a district or area subject to 'blistering.'

c. A site within each coastal district that will permit the undertaking (1) of investigation of at least one or more embankment that shows a surface crack in the normal concrete armor and of at least one or more embankment that does not show the aforementioned crack and (2) of study to determine the relationship between the above two, in accordance with the investigation mode outlined in Table 6.1

"Based on the principles described above, some 445 different sites were investigated. The result of the investigations showed that weep/air holes were found in only 27 sites, or about 6.1% of the total and that these were sites all located in the coastal area of

Mikawa Wan. One of the reasons for the confinement of the weep hole discovery to the Mikawa Wan area embankments could be attributed to the fact that in the site selection process, a number of sites in the Ise Wan coastal area were eliminated because of the change in the functional requirements of embankments in this area brought about by expanding reclamation work. Information on the weep holes discovered at the 27 sites is provided in Table 6.1. The developmental causes for these weep holes, as studied and analyzed by the Nagoya Research Institute of Industrial Technology, were as follows:

a. Uneven sinking between the normal concrete armor and the embankment earth and sand caused by the sinking of the base from the weight of the embankment and development of air gaps from the compaction of embankment soil.

b. Erosion of embankment earth and sand caused by high and low tides and water action and development of weep holes through natural erosion action.

c. Seepage of rain water, etc., into the embankment normal armor from its natural expansion and contraction phenomena causing the shift in embankment earth and sand to develop air gaps.

Of the 27 sites, 20 were categorized as those that fell under a above, five under b above, and two under c above.

"In the on-the-spot investigations that were conducted, very minute air holes that were not as distinct a hole as those observed in the 27 sites were also detected in other sites. These, for the most part, were those very minute natural gaps that developed between the normally laid concrete armor and the embankment earth and sand in a two-layer armor structure of filled pebbles. Similar type of air gaps of 1-2 cm was also observed in structures where asphalt foundation had been constructed under the normal concrete spread. Though these 1-2 cm gaps do not strictly come under the accepted category of an air hole, they were widely observed in this investigation, particularly in those embankments that did not show any surface breaks, such as concrete cracks. They are not posing as an immediate threat to the embankments, but their development is a matter that will require attention in the future."

Table 6.1 - Table on Survey Results of Weep/Air Holes and Air Gaps/Openings

表－6.1　空げき・空洞調査結果一覧表

(1) 番号	(2) 空げき・空洞の位置	(3) 空げき・空洞の深さ（cm）	(4) 空げき・空洞の大きさ（推定）(m³)	(5) 原因	(6) 完成時からの沈下量（cm）	(7) 地盤状況
1	(8) 裏	1	20	(9) 圧密または圧縮沈下		(10) N値10以下のCL層が9m堆積している。（CL＝粘性土）
2	(11) 表	50	0.02	建設当時より？ (12)		軟弱な粘土層はない。(13)
3	(11) 表	1	1	(14) 堤体と地盤の圧密	4	N値6以下のゆるい砂層が8m程度あるが粘土層はない。(15)
4	(11) 表	3	50	地盤の圧密沈下 (16) 堤体の圧縮 (16a)	2	N値0～1のCL層3.5m (17) N値4のSF層3m（SF＝砂質土）(17a)
5	(18) 天端	10～15	−	地盤の圧密沈下 (19)		N値7以上の固いCH層が15m存在する。(20)
6	(11) 表	3～4	25	地盤の圧密沈下 (19)		6mのCH層がある。（CH＝粘土）(21)
7	(8) 裏	2～3	30	地盤の圧密沈下，吸出し (22)		6mのCH層がある。(23)
8	(8) 裏	50	0.78	建設当時より？ (12)		砂レキ層のみで軟弱粘土層はない。
9	(11) 表	1		堤体の圧縮 (24)		全体としては砂レキ層が発達している。(25) −10m付近にN値3のCH層が6mある。
10	(11) 表	1	600	堤体の圧縮，浸透水による土の流出 (26)		〃
11	(11) 表	3	260	堤体の圧縮 (12)	13	
12	(11) 表	1	340	背面の盛土のスベリ目地から水が入る (27)	16	N値0～1のCL層が5m，この層の下にN値3程度のS.CL全層が5mある。（S＝砂）(28)
13	(11) 表	2	1,300	〃		N値0～1のCL層が5m，この層の下にN値3程度のS.CL全層が5mある。（S＝砂）(28)
14	(8) 裏	2	1,500	〃		〃
15	(11) 表	30	2	吸出し (29)		N値10～20の砂層が10mあり，その下にN値7～9の固いCH層がある。(30)
16	(11) 表	5	200	浸透水による土の流出		軟弱な粘土層は全然ない。(32)
17	(11) 表	5	600	〃		軟弱な粘土層は全くない。(32)
18	(8) 裏	2～3	−	堤体と地盤の圧縮 (14)	5	砂層および風化花崗岩層 (33)
19	(18) 天端	5	550	吸出し (29)		N値10以上の砂レキ層が発達 (34)
20	(18) 天端	8	550	〃		〃
21	(18) 天端	5	3	堤体中の浸透流による土の流出 (35)	4	砂層のみが発達している。N値7の砂層が4mあり，それより下はN値20以上 (36)
22	(18) 天端	5～15	15	〃		〃

(Continued Table 6.1)

1 番号	2 空げき・空洞の位置	3 空げき・空洞の深さ (cm)	4 空げき・空洞の大きさ (推定)(m²)	5 原因	6 完成時からの沈下量 (cm)	7 地盤状況
23	11 表	2	25	地盤の圧密沈下 17	3	N値0のCL層が2m程度あり，その下はN値20以上の砂層 27
24	18 天端	5	30	〃		N値0～1のCL層が6～10m程度存在する。 28
25	〃	5	20	〃		〃
26	11 表	3	15	〃		〃
27	8 裏	7	20	〃		〃

Key to Table 6.1:

1. Site Number
2. Location of Weep Hole or Air Gap
3. Depth of Weep Hole or Air Gap
4. Size of Weep Hole or Air Gap (Estimate)(m^2)
5. Cause
6. Sinking Since Construction (cm)
7. Condition of Base
8. Rear spread
9. Sinking from consolidation or compression
10. 9m sedimentation of CL layer of N-value 10 or below (CL= clayish/clayey soil)
11. Face spread
12. From the time of construction?
13. No weak and soft clay layer
14. Consolidation of embankment and base
15. There are about 8 m of loose sand layer of N-value 6 or lower but no clay layer.
16. Consolidation sinking of base

16a. Compression of embankment
17. 3.5m of CL layer of N-value 0-1
17a. 3m of SF layer of N-value 4 (SF=psammitic soil)
18. Crown edge
19. Consolidation sinking of base
20. There are 15 m of hard CH layer of N-value 7 or higher.
21. There are 6m of CH layer. (CH=clay)
22. Consolidation sinking of base; erosion
23. There are 6 m of CH layer.
24. Compression of embankment
25. Generally speaking, the pebble layer is well developed.
26. Compression of embankment; soil erosion from water permeation
27. Slippage of raised back ground; permeation of water from ground site
28. There are 5 m of CL layer of N-value 0-1, and below this, 5m of complete S.CL layer of N-value 3 (S=sand)

(Continued Key to Table 6.1)

29. Erosion
30. There are 10 m of sand layer of N-value 10-20, and below this, hard CH layer of N-value 7-9.
31. Soil erosion from water permeation
32. Absolutely no soft or weak clay layer
33. Sand layer and efflorescence granite layer
34. Well-developed pebble layer of N-value 10 or higher
35. Soil erosion from permeation flow inside the embankment
36. Well-developed sand layer only; there are 4 m of sand layer of N-value 7; below this, N-value 20 or higher.
37. There are about 2 m of CL layer of N-value 0; below this, sand layer of N-value 20 or higher.
38. There are 6-10 m of CL layer of N-value 0-1.

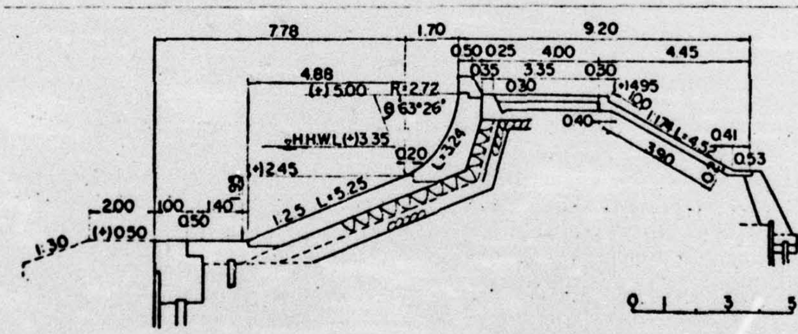
B. Coastal Survey to Clarify the Relationship Between Weep/ Air Holes and Air Gaps and Wasting Indicators

A very high reliability could be placed on the coastal embankment survey findings of Aichi prefecture since the method employed was to remove the covering to observe directly/vividly if there was or was not a weep hole or air gap inside an embankment. It was felt that if the visible embankment changes that have been observed in the on-the-spot survey that had been conducted could be correlated with the external conditions of the embankments where the weep holes and air gaps had been observed in Aichi prefecture, a better understanding of the relationship between the aforementioned observed changes and the weep holes and air gaps could be gained. For this reason, we sought and gained the permission of the Aichi prefectural authorities to conduct investigation of the embankments in this prefecture. The investigation covered 13 embankment sites including 8 of the aforementioned 27 sites where weep holes and air gaps had been observed. Chart 6.3 - 6.13 show cross-section views of the embankments investigated, Photo 6.1-6.51, investigation findings, and Table 6.2, external changes that were observed.

a. Coastal Embankment A-1 (see Chart 6.3, Photo 6.1-6.4)

The embankment is located deep inside the Koromoga Ura Wan, way beyond the central wharf. Extensive reclamation work has been performed near the site to discount the possibility of serious wave action. It is a three-side concrete armor, masonry embankment that was constructed after the disastrous Typhoon No 13. The face spread showed an oblique and a horizontal direct line crack, the latter near the adjoining wave deflector ground site (presumbaly caused by the larger size difference of the parapet section as compared to the face spread armor), but they were relatively small-sized and unexposed cracks. The rear spread armor was exposed near the indentation of the shoulder (possibly due to poor construction) and showed a horizontal direction crack near the center and a crack near the tail end. According to the Aichi prefectural survey report, about a 1 cm gap was detected between the rear spread armor and the embankment core and it was assumed that this gap extended beneath the whole rear spread armor. Grout has been poured into this gap to fill up this air gap.

Chart 6.3 - Cross-section View of Coastal Embankment A-1



図－6.3 海岸堤防A－1標準断面図

Photo 6.1 - Normal Line Direction Crack of Face Spread

写真-6.1 表のり工法線方向のクラック

Photo 6.2 - Level Difference Between Crown and Rear Spread at Ground Site

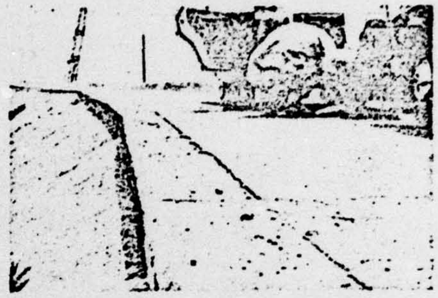


写真-6.2 天ば工と裏のり工との目地の段差

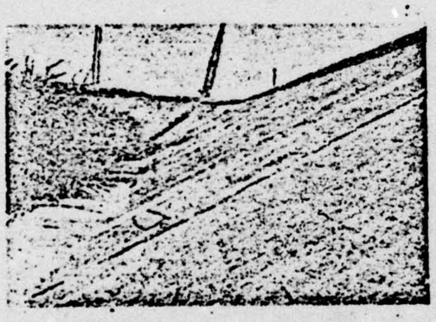


写真-6.3 裏のり工のはらみ

Photo 6.3 - Exposure of Rear Spread

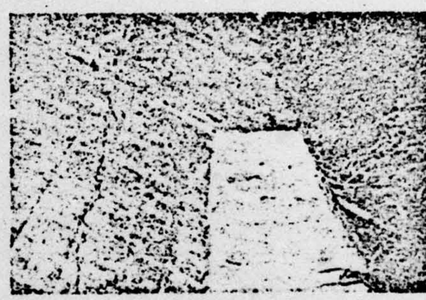


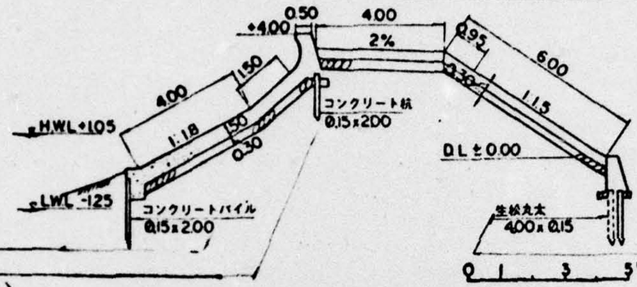
写真-6.4 裏のり工法線方向のクラック

Photo 6.4 - Normal Line Direction Crack of Rear Spread

b. Coastal Embankment A-2 (see Chart 6.4, Photo 6.5-6.9)

This embankment is located inside the Koromoga Ura Wan but much farther in than embankment A-1, and thus, it is believed that the wave action it is encountering is neglible. From the exterior, it appears to be a solid structure, but the conjecture is that there are air gaps beneath the face and rear spread armors and for this reason, mortar pouring job has been scheduled. Visible outside changes that have been observed include, as shown in the photos, abrasion or angular break (believe this to be the result of poor material used) of face spread, face spread edge, and face spread center part, crack that extends from the face spread to the parapet, vertical aberration of rear spread armor at the vertical ground site, etc. According to the Aichi survey report, about a 3 cm gap has been observed in this embankment.

Chart 6.4 - Cross-section Sketch of Coastal Embankment A-2

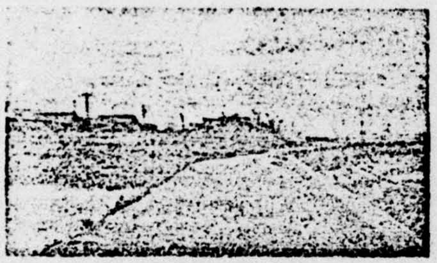


oncrete
ile

oncrete
take/pole

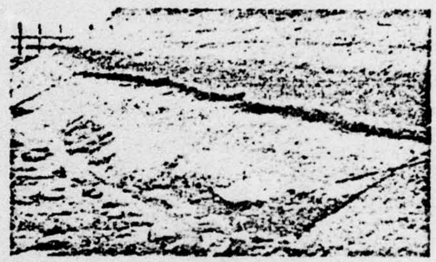
Raw pine
log

図－6･4 海岸堤防A－2標準断面図



写真－6.5 全景

oto - 6.5
General
e



写真－6.6 表のり工下部の打継目に生じた角欠け

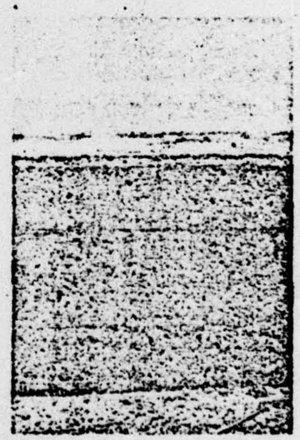
Photo 6.6 - Angular Break Tha
Developed at th
Lower Section o
Face Spread

写真－6.7
感潮部コンクリートの劣化

Photo 6.7 - Wasting of Tidal Section Concrete

写真－6.8 表のり工全面にわたる
断面方向クラック

Photo 6.8 - Example of Section Direction Cracks Throughout the Face Spread



写真－6.9 波返し工のクラック

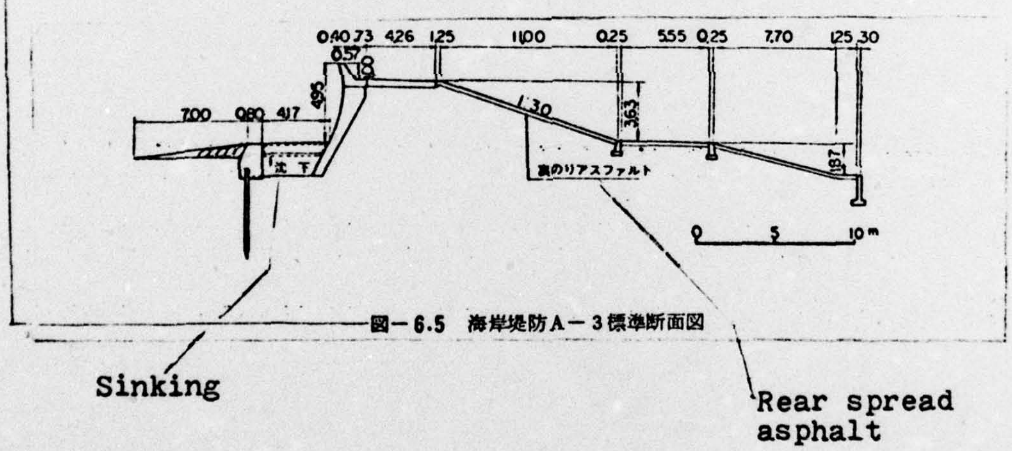
Photo 6.9 - Crack of Wave Deflector

c. Coastal Embankment A-3 (see Chart 6.5; Photo 6.10-6.13)

This embankment is located at the mouth of Yahagi Gawa with a beach to the front, but is encountering, it is believed, relatively heavy action of the waves. Both the face spread and the foundation steps are constructed of concrete and the front and rear spreads are provided with asphalt concrete coverings. In one section of the asphalt-concrete coverings, there is a crack, but no other deteriorations, such as exposure, cave-in, etc., were observed. Due to insufficient coverings, exposure of ferro-concretes was observed in the face spread armor and parapet sections. Sinking of the foundation steps was also noted. Reinforced bedding has been constructed of rip-rap concrete to fill up any air gaps.

Weep holes were observed near the bedding anchor as localized holes. These holes, it is believed, were caused by the shift in embankment soil from the permeation of rain water or from the change in the water level of the rear "shio asobi" [literally, "tidal play"].

Chart 6.5 - Cross-section Sketch of Embankment A-3



図—6.5 海岸堤防A—3標準断面図

Photo 6.10 - Small Step Slab Sinking of Reinforced Concrete Section

写真-6.10 根固部の小段スラブの沈下

Photo 6.11 - Exposure of Ferro-Concrete of Wave Deflector

写真-6.11 波返し工の鉄筋の露出

写真-6.12 裏のり工(アスファルトコンクリート被覆)

Photo 6.12 - Rear Spread (Asphalt concrete covering)

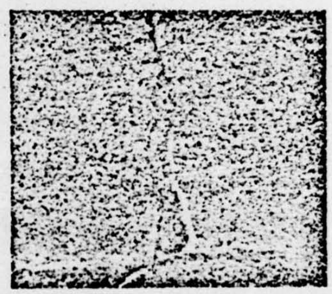


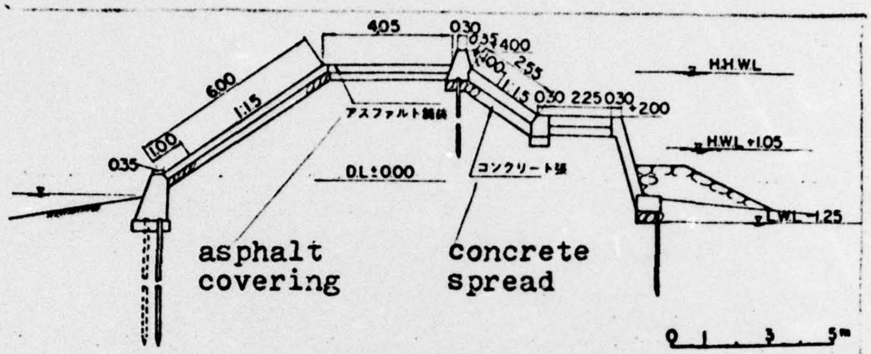
写真-6.13 裏のり工のクラック

Photo 6.13 - Crack of Rear Spread

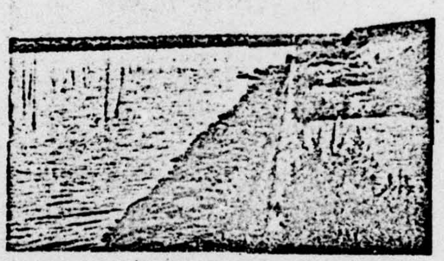
d. Coastal Embankment A-4 (see Chart 6.16, Photo 6.14)

This embankment faces the waterway that passes through Teratsu Harbor and thus, is not encountering any direct action of the waves. It was constructed atop an old masonry rip-rap after Typhoon No 13. The face spread is provided with small steps and is supported by reinforced bedding. The crown is covered with asphalt concrete. A concrete block cave-in was observed in the step section of the face spread; grass is growing at the ground site. The even slope rear spread is provided with a concrete armor, but a vertical aberration was observed at the vertical ground site. Grass is also growing at this site. The back is a "shio asobi" [tidal play?] area. The aforementioned Aichi survey report stated that a 1-cm air gap was found below the face spread armor.

Chart 6.6 - Standard Cross-section Sketch of Coastal Embankment A-4



図－6.6 海岸堤防A－4標準断面図



写真－6.14 表のり工および根固工の状況

Photo 6.14 - Conditions of Face Spread and Reinforced Bedding

e. Coastal Embankment A-5 (see Chart 6.7, Photo 6.15 - 6.18)

This embankment is located much farther inside than embankment A-4 and is constructed about the same as A-4, structurally. The concrete block of the upper step section of the face spread showed a cave-in (similar to A-4); a 5-cm or more vertical aberration of the vertical ground site was also observed. According to the Aichi survey report, about a 3-cm air gaps were observed beneath the face spread armor.

Chart 6.7 - Standard Cross-section Sketch of Embankment A-5

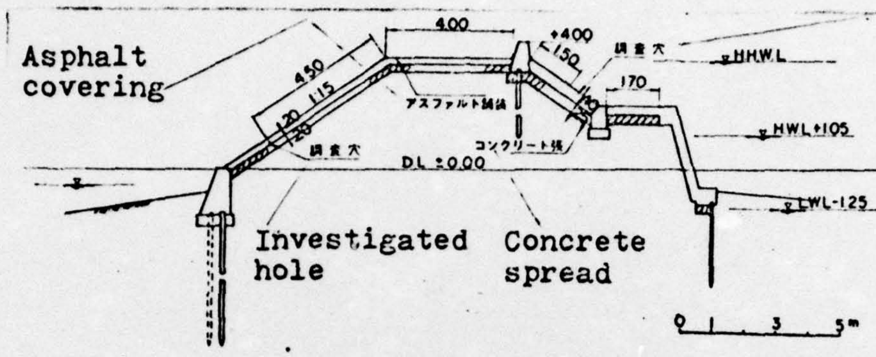


図 - 6.7 海岸堤防A - 5標準断面図

写真 - 6.15 表のり工および根固工の状況

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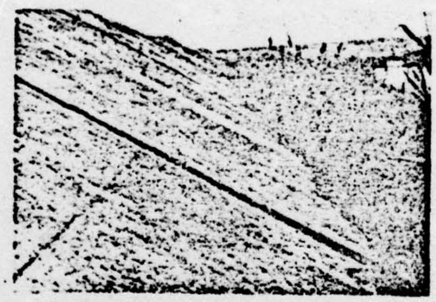


写真 - 6.16 裏のり工のはらみ

Photo 6.16 - Exposed Face Spread

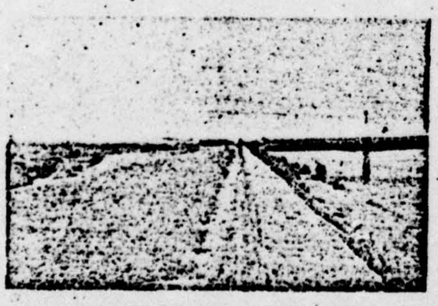


写真 - 6.17 波返し工法線の変形

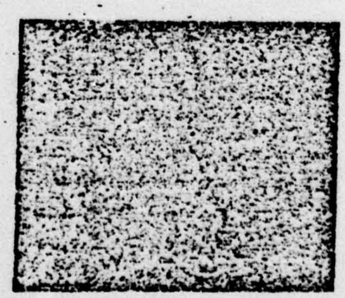


写真 - 6.18
表のり工に生じた法線直角方向クラック

Photo 6.17 - Normal Line Contour Change of Wave Deflector

Photo 6.18 - Normal Line Right Angle Crack That Developed in Face Spread

f. Coastal Embankment A-6 (see Chart 6.8, Photo 6.19-6.22)

This embankment is located in an araa pinched in by the waterway and Okuda: Nitta. No strong action of the waves, it is believed, is being faced by this embankment. The face spread is provided with small steps and the whole front is supported by reinforced bedding; external observation shows no unusual change in the whole face spread. The crown is covered with asphalt concrete and also shows no deterioration. The rear spread shows some exposure but is provided with concrete armor; few cracks were observed in the rear spread and a patch of growing grass was observed near its connection with the bedding anchor. According to the Aichi survey report, about a 1cm air gap was observed beneath the face spread armor.

Chart 6.8 - Standard Cross-section Sketch of Coastal Embankment A-6

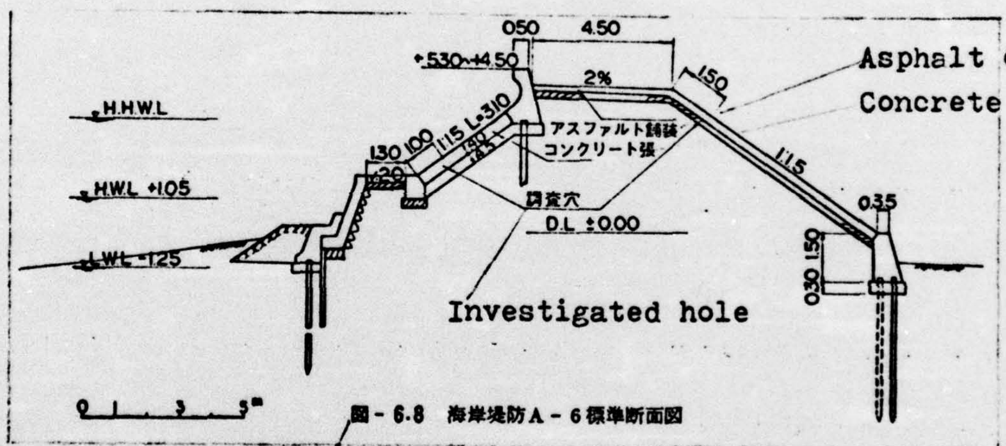
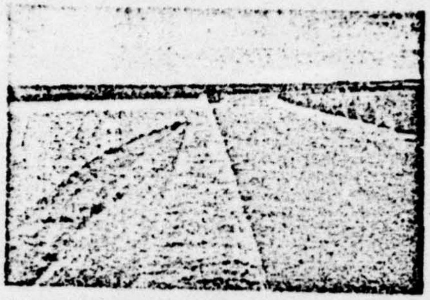


図-6.8 海岸堤防A-6標準断面図



oto 6.19 - 写真-6.19 表のり工および波返し工
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写真-6.20 裏のり工の法線直角方向のクラック - Photo 6.20 - Normal Right Angle Crack of Rear Spre

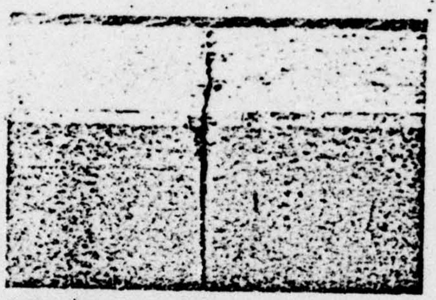

写真-6.21
波返し工の目地の間隙（目地板が脱けたもの）

Photo 6.21 - Opening at the Ground Site of Wave Deflector (breach of ground site block)

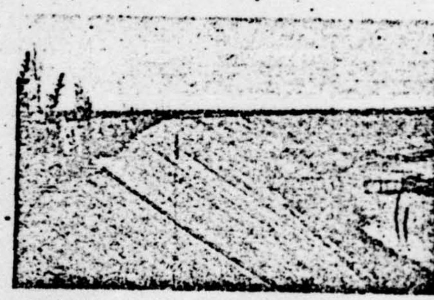

写真-6.22 裏のり工および根留工の状況

Photo 6.22 - Conditions of Rear Spread and Bedding Anchor

g. Coastal Embankment A-7 (see Chart 6.9, Photo 6.23-6.28)

The cross-section of this embankment is almost the same as A-6 but this embankment has a concrete block cave-in block in the step section of the face spread and its reinforced bedding to the front showed scattering near the sluice. The latter development is believed to have been caused by the conversion of waves resulting from the breakwater located on the western side of the sluice. At the vertical and horizontal ground sites of the rear spread armor, big breaks and vertical aberrations were observed. Thick growing grass was observed near the pile joint of the bedding anchor as well on the crown. According to the Aichi survey report, a 2 cm air gap was observed beneath the face spread armor.

Chart 6.9 - Standard Cross-section Sketch of Embankment A-7

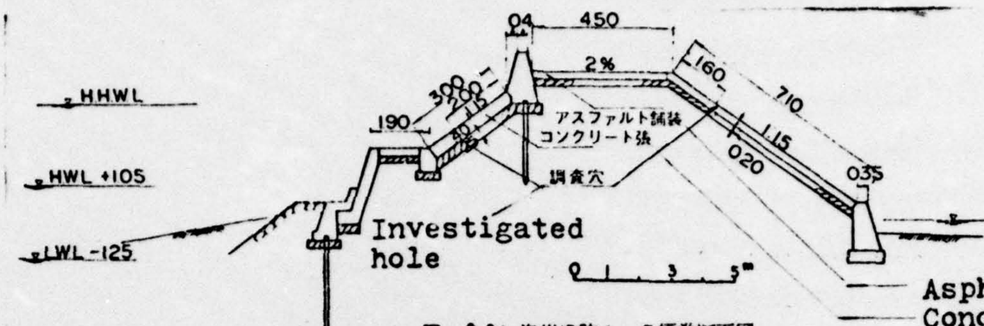

図 - 6.9 海岸堤防A - 7標準断面図

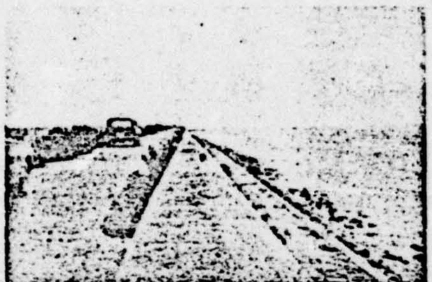

写真 - 6.23 表のり工および波返し工

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Wave Re-
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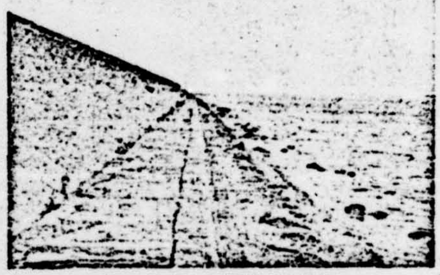

写真 - 6.24 根固工の状況

Photo 6.24 - Condition of Reinforced Bedding

写真 - 6.25 樋門付近の汀線の後退

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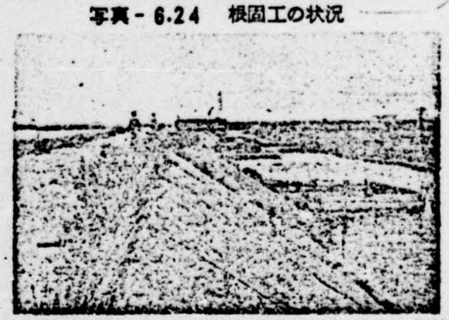

写真 - 6.26 裏のり工と天ば工の目地にはえた雑草

Photo 6.26 - Mixed Grass Growing at the Ground Site of Rear Spread an Crown

写真 - 6.27 裏のり工のスラブの折れ

Photo 6.27 - Rear Spread Slab Break

写真 - 6.28 裏のり工スラブの移動による段差

Photo 6.28 - Uneven Level of Rear Spread Caused by Slab Shifting

h. Coastal Embankment A-8 (see Chart 6.10, Photo 6.29-6.32)

This is a 3-level sea wall structure with a parapet constructed on the top and a reclaimed ground to the rear. The apron was an asphalt-concrete covering that was employed as a roadway. This covering was removed because of 5-6 cm sinking and a big air hole was discovered below. It was assumed that the cause for this development was the soil erosion from the ground site of the front block. The discovery led to the removal of the whole covering to repack the soil below and to recover the whole blocks with concrete reinforced by use of cords. A year after this renovation work, however, the reinforced coverings with cord began to chip off, leading to the sinking of the coverings. Present plan calls for the placement of sheet pilings to correct the above situation. The reinforced bedding to the front appears to be in good condition, showing no shifting of any kind despite the fact that it has been in existence for about 10 years since its construction.

Chart 6.10 - Standard Cross-section Sketch of Embankment/Sea Wall A-8

Investigated hole

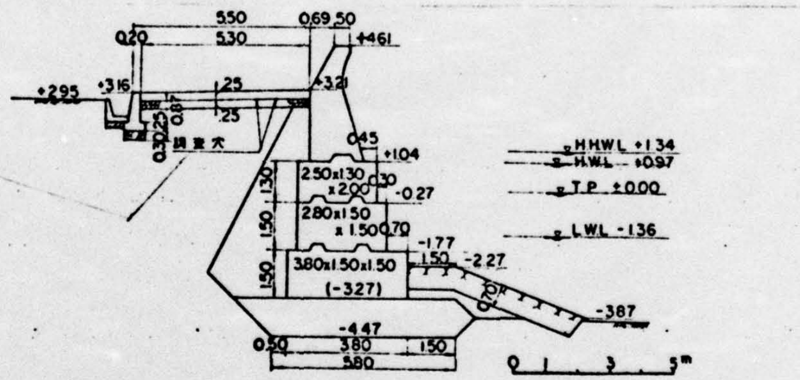

図-6.10 海岸堤防A-8標準断面図

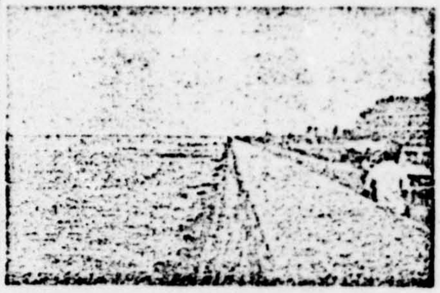

写真-6.29 波返し工と表のり工の状況

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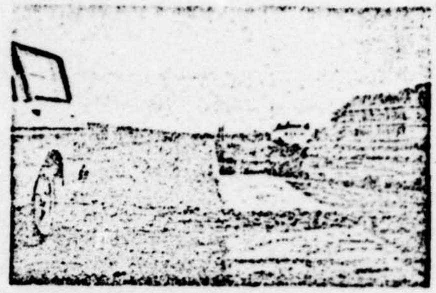

写真-6.30 天ば工および堤内の状況

Photo 6.30 - Conditions of Crown and Inside the Embankment

写真-6.31 護岸前面および根固工の状況

Photo 6.31 - Conditions of Front of Sea Wall and Reinforced Bedding

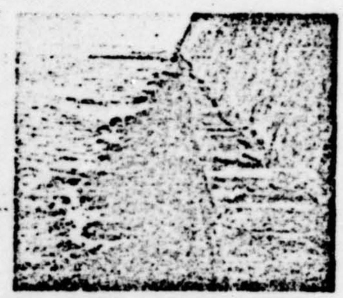

写真-6.32 表のり下部の鉄筋の露出

Photo 6.32 - Exposed Ferro-concrete of Lower Section of Face Spread

i. Coastal Embankment A-9 (see Chart 6.11, Photo 6.33-6.37)

This embankment is located deep inside the Mikawa Wan in a location where the terrain serves as a barrier against any serious action of the waves. Extensive reclamation work is being undertaken to the front to indicate that in due course of time, this embankment will be facing quiet sea water to the front. Almost no deterioration was observed in the originally constructed reinforced bedding. The face spread armor, however, did show a horizontal direction concrete abrasion near the end of the armor as well as angular breaks and cracks (part of the larger cracks of the spread have been repaired by concrete mending). The rear spread armor also showed a break at the vertical ground site and at the pile joint of the bedding anchor and an erosion of the soil at the shoulder; a number of cracks were also observed in the rear spread. This embankment was not listed as one of the weep-hole sites in the Aichi survey report, but was a suspect site. For this reason, grout pouring work has been carried out so far.

Chart 6.11 - Cross-section Sketch of Coastal Embankment A-9

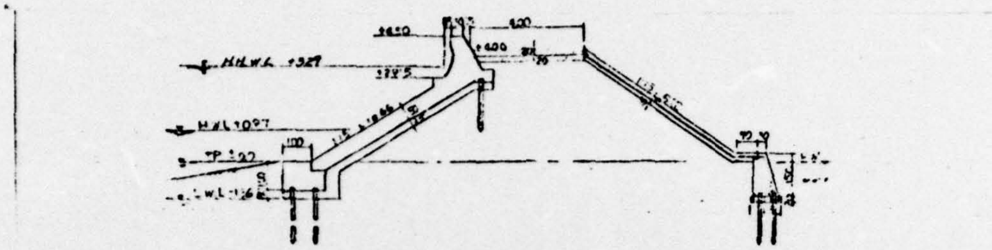

図-6.11 海岸堤防A-9標準断面図

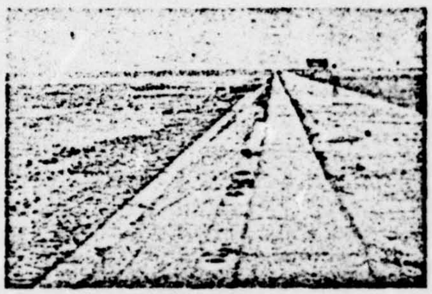

写真-6.33 全景

o 6.33 -
erel View

写真-6.34 表のり被覆工（天ば工との目地の段差）

Photo 6.34 - Rear Spread Armor (Level Difference With Crrown at the Ground Site)

写真-6.35 表のり工下部
コンクリート打継目の角かけ

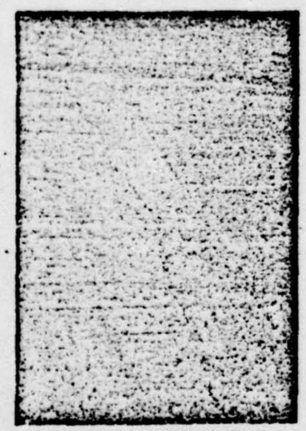

写真-6.36 表のり施工
目地近くの法線直角方向クラック

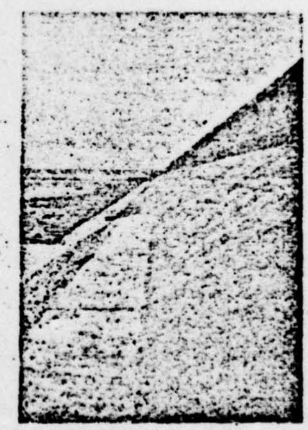

写真-6.37
表のり下部の腹付けコンクリート

Photo 6.35 - Angular Break of Lower Section of Face Spread at Concrete Pile Joint

Photo 6.36 - Normal Line Right Angle Direction Crack of Face Spread Near Work Site

Photo 6.37 - Added Concrete At the Center Section of the Lower Part of Face Spread

j. Coastal Embankment A-10 (see Chart 6.12, Photo 6.38-6.43)

This is a three-side concrete armor embankment that was constructed over a foundation that a masonry embankment stood before it was destroyed by Typhoon No 13. With the exception of few cracks, the face spread appears almost the same since its completion, but a soil erosion near the shoulder, breach with the bedding anchor near the pile joint, and a crack near the center armor were observed in the rear spread.

Chart 6.12 - Standard Cross-section Sketch of Coastal Embankment A-10

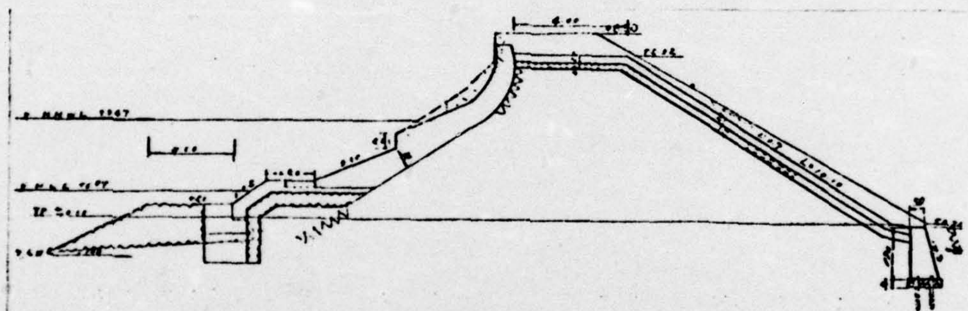

図-6.12 海岸堤防A-10標準断面図

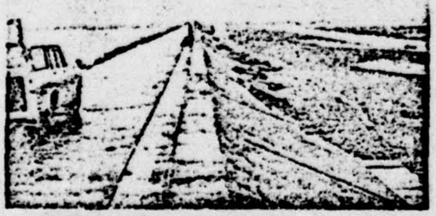

写真-6.38 表のりおよび波返し工

Photo 6.38 - Face Spread and Wave Reflector

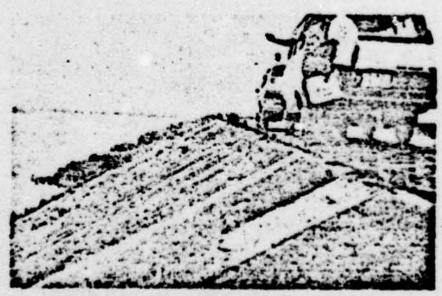

写真-6.39 裏のりおよび潮遊び

Photo 6.39 - Rear Spread and "shio asobi" ["tidal plan?"]

to 6.40 - 写真 - 6.40 波返し工のクラック
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l ctor

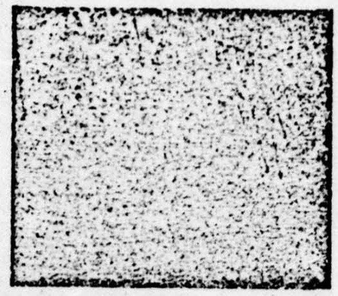

写真 - 6.41 表のりの法線直角方向クラック - Photo 6.41 - Normal Line Right Angle Crack of Face Spread

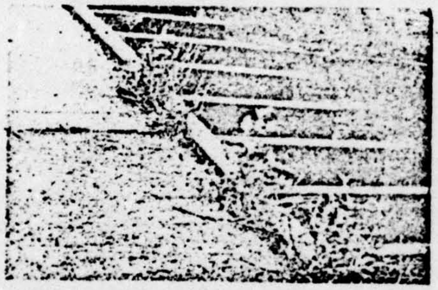

写真 - 6.42 天ば工の沈下による段差

Photo 6.42 - Level Difference Caused by Sinking of Crown

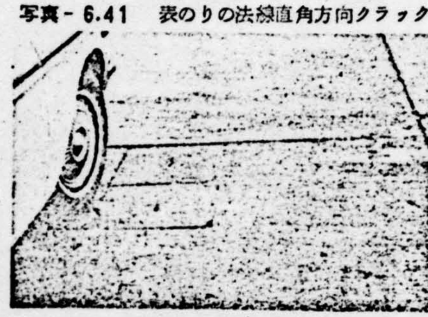

写真 - 6.43 天ば工のマンホール

Photo 6.43 - Man-hole of Crown

k. Coastal Embankment A-11 (see Chart 6.13, Photo 6.44-6.48)

This embankment is located outside the breakwater of Koromoga Ura Wan. The designed tide grade after the Ise Wan typhoon was + 7.50, but at the time of strong waves, the waves splashed over the crown. The front sand did show seasonal type of movements, but there appeared, however, no loss of the sand.

Angular breaks and abrasion were observed in the face spread armor near the work site, but concrete repair work had been performed on severe breaks. Generally speaking, the mixture of concrete seemed rather poor, but except for the above deteriorations, no other serious breakdown was noted. Because of fairly high back base, the rear spread profile was very low in comparison. The rear spread showed some exposure but no crack or unusual change. In the Aichi survey, no weep hole or air gap was found, but spread concrete had been employed to repair the upper part of the face spread where many cracks had developed, and grout for the lower part. This embankment was restored after Typhoon No 13 and its face spread armor is only about 30 cm thick.

Chart 6.13.- Standard Cross-section Sketch of Coastal Emgankment A-11

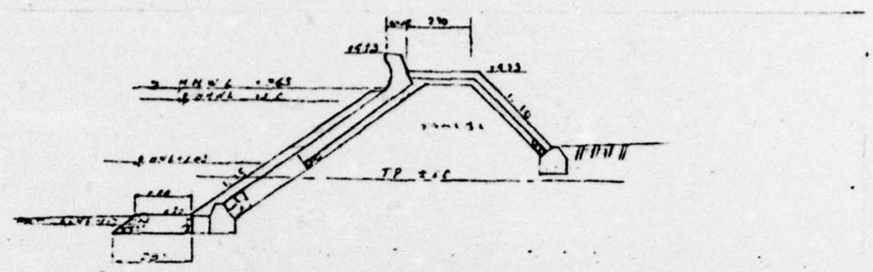

図-6.13 海岸堤防A-11標準断面図

写真-6.44 全景（腹付けコンクリート）

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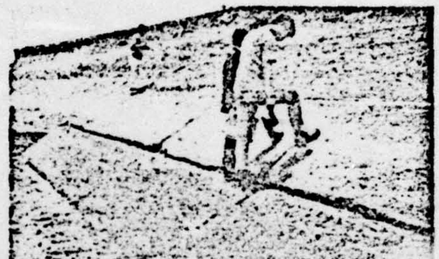

写真-6.45 表のり下部のコンクリート打継目の角欠け

Photo 6.45 - Angular Break of Concrete Pil Joint of Lower Sectic of Face Spread

写真-6.46
表のり下部の目地部の角欠け

Photo 6.46 - Angular Break of Face Spread Lower Section at Ground Site

写真-6.47 波返し工
の目地の不陸と表面の摩耗

Photo 6.47 - Surface Abrasion and Soil Erosion at Ground Site of Wave Deflector

写真-6.48
表のり被覆コンクリートの摩耗

Photo 6.48 - Concrete Abrasion of Rear Spread Armor

Table 6.2 - Wasting Indicators Observed in Aichi Prefecture Coastal Embankmen

表－6.2 愛知県海岸堤防にみられる劣化指標

[illegible]	A－1	A－2	A－3	A－4	A－5	A－6	A－7	A－8	A－9	A－10	A－11
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Key to Table 6.2:

1. Coastal Embankment
2. Year Constructed
3. Changes Observed Externally
4. Front Side: S 34-38 /Note: "S" refers to Showa; thus to get the year, add 25; e.g., S 34-38=34+25 and 38+25 or 1959-1963; same below and across the column/
5. Back side: S 36-38
6. Additional repair in mid-section
7. Foundation
8. Condition of reinforced bedding rip-rap
9. Erosion of blocks from wave action
10. Erosion
11. None (within inner Koromo-ga Ura Wan)
12. Partial dispersion/scattering
13. None (inside the Wan/bay)
14. Good (rip-rap and concrete pieces)
15. No dispersion/scattering
16. None
17. Reinforced bedding shift in sluice section
18. No scattering/dispersion (since 10 years ago when first constructed)
19. Face spread armor
20. Normal line exposure of face spread
21. Normal line right angle direction exposure
22. Normal line right angle direction crack exposure
23. Normal line right angle direction cave-in
24. Angular break of face spread material
25. Abrasion
26. Damage
27. Surface rusting
28. Break in face spread at the ground site
29. Angular break of face spread at the ground site
30. Vertical aberration of face spread at the ground site
31. Internal surface aberration of face spread at the ground site
32. Break of horizontal ground site
33. Angular break
34. Vertical aberration
35. Internal surface aberration
36. Break at pile joint of foundation
37. Angular break at the pile joint of foundation
38. Vertical aberration at the pile joint of foundation
39. Break of pile joint of parapet
40. Angular break of the pile joint of parapet
41. Aberration of the pile joint of parapet
42. Normal line direction crack
43. Normal line right angle direction crack
44. Found in one section
45. Observed/found
46. Break
47. Ground site
48. Unknown
49. Crack
50. Along the work site of parapet; also corner angle section
51. About 3-5 pitch, top to bottom
52. Angular break of ground site
53. Found/observed (insufficient covering to expose the ferro-concrete)
54. About 5 cm
55. Found (foundation work)
56. Rip-rap concrete
57. Danger of erosion
58. No horizontal ground site
59. Some grass growing
60. Found (9 sites/entire length)
61. Found (12 sites/entire length)
62. Found (1cm; weak)
63. Found (concrete wasting of reinforced bedding section

(Continued Key to Table 6.2)

64. Break; cave-in
64a. Found (8 sites/entire length)
65. A weep hole was found behind the back of the block-type sea wall and as a result, the area was sealed with concrete, making survey difficult; general situation unknown and no unuusual development observed at the present time.
66. Found (Normal line level drain situation near the end of face spread)
67. None - depth: 15 cm
68. None - width: 10 cm
69. None - length: 6 cm
70. Found (end section of face spread)
71. Found (very little)
72. Found (portion of structural materials exposed)
73. Found (near horizontal ground site)
74. Found (center of span)
75. Wave deflector
76. Indentation of normal line
77. Angular break of materials
78. Abrasion of materials
79. Damage to materials
80. Surface rusting of materials
81. Break at the ground site
82. Vertical aberration of ground site
83. Front and back aberration of ground site
84. Normal line right angle direction water level/standard crack
85. None (slight soil erosion)
86. 0.5-0,7 cm level aberration
87. None (crack connected from wave deflector to face spread)
88. Found (poorly mixed concrete)
89. Found (connected to face spread crack)
90. Found (15 cm ground site block with + 0.3 cm)
91. Found (3-5 cm pitch)
92. Found (3 cm)
93. Found (0.2-0.3 cm break between cracks)
94. None (poor mixture [of concrete?])
95. Found (5 m pitch)
96. Found (in the connecting section with face spread)
97. Crown armor/covering
98. Soil erosion of crown
99. Angular break of materials
100. Break at the work site
101. Break with wave deflector at the work site
102. Break with rear spread at the work site
103. None (due to rear spread sinking or from the very beginning)
104. Asphalt covering
105. Asphalt-concrete covering
106. In anticipation of sinking at the time of construction, the covering was laid 1-2 cm higher.
107. Fairly large grass growing area.
108. Found (1 cm)
109. Found (one section)
110. Found (8-10 cm)
111. Found (3 cm)
112. Rear spread armor
113. Normal line direction exposure of rear spread
114. Normal line right angle "hoshutsu no shiyorami dashi" [sic; "exposure from released tidal 'rami' (sic)"]
115. Normal line right angle direction crack exposure
116. Normal line right angle direction cave-in
117. Soil erosion of shoulder

(Continued Key to Table 6.2)

118. Surface rusting
119. Break at vertical ground site
120. Angular break at ground site
121. Vertical aberration at ground site
122. Internal surface aberration of ground site
123. Break at horizontal ground site
124. Break with pile joint of bedding anchor
125. Crack (normal line direction)
126. (Normal line right angle direction)
127. None (Sinking of rear spread)
128. Connected
129. Just a little: 0.5 cm
130. A few in one section
131. Found in 15 sites (whole length)
132. About 3-5 cm in the curve section; pitch length 1m crack
133. Found (24 sites/whole length)
134. Found - 5 cm
135. Found (grass growing)
136. Found (12 sites/whole length)
137. Found (only slight exposure)
138. None (some grass growing)
139. Vertical ground site
140. Horizontal ground site
141. Found (1-2 cm pitch)
142. Found (only slightly)
143. Found (8-10 cm)
144. Found (grass growing)
145. Found (fairly large number)
146. Found (3 cm)
147. Found (in ground site block)
148. Break
149. Found (inside the block)
150. Found (poor mixture)
151. - (no bedding anchor)
152. Weep Holes Survey Results of Aichi Prefecture
153. Location of Weep Holes/Air Gaps
154. Rear spread
155. Face spread
156. Crown
157. No weep hole investigation was conducted, but fearful of the existence of weep holes and air gaps, mortar injection was carried out and foundation was reinforced with concrete work.
158. No investigation conducted
159. Depth: cm x size (m^2)
160. Cause
161. Consolidation
162. Cause by erosion
163. Embankment soil texture
164. Pebbles mixed with earth and sand
165. Sand
166. Mountain soil
167. Sandy soil
168. Soil texture to the front
169. River to the front
170. Sandy soil (river to the front)
171. Crack situation of surrounding area
172. Very little
173. None

TRANSLATIOR'S NOTE

Page 72 of the original text missing.

The "isshoku" [literally, "one color"; possibly implying "all"] embankments of Mikawa Wan have a crown tip of TP + 5.20 m, a bedding anchor with an upper tip of ± 0.0-0.50 m, and a rear spread, whether single or multiple layer, with a spread slope of 1:1.5. When a multiple layer, there is a water level section of 2.0-4.0 m in the mid-section of the spread surface. The bedding anchor is a concrete block foundation post that stands about 1.0 m high, or a concrete double stack that stands about 1 m high. The armor/covering thickness is about 30 cm including foundation rip-rap of about 15 cm and concrete thickness of about 15 cm. Weep hole investigation was conducted in this district, but none was found. This could have been the result of the severe damages that had occurred to the armors/coverings to destroy the weep holes and air gaps before the investigation was conducted.

No detailed investigation was conducted, but from the specifications standpoint of the aforementioned rear spread and bedding anchor, it can be concluded that they are far from adequate to withstand the earth pressure of this high embankment. This fact, it is believed, led to the pushing forward of the bedding anchor to cause the sliding of the rear spread armor, to the break and aberration in the ground site (block thinness also a contributing factor), and to the cracking in the block. The chain reaction from the above development was the break and aberration at the joint of the crown, the shift in the embankment earth and soil through seepage of rain water and overtopping waves, and the development of crack in the crown. In the on-the-spot survey conducted, very severe normal line direction crack of the crown was observed as well as very heavy mixed grass growth at the upper and lower edges of the rear spread.

Table 6.3 - Height of Embankment and Rear Spread Condition

表 - 6.3 堤防の高さと裏のりの状態

① 海岸堤防	② 天ば工高 (A)	③ 根留工高 (B)	④ 差 (A)-(B)	⑤ 勾配 (平均)	⑥ 裏のり工 長さ m	厚さ 版厚 路盤厚	⑦ 根留工	⑰ 裏のりの状態
A	+5.00	+2.6	·2.60	1:1.57	4.36	20 30	2mの上部工に 基礎矢板	○
B	+4.0	+0.0	4.00	1:1.5	6.00	20 20	1mの上部工に 基礎丸太	△ 縦目地ずれ
C	+3.5	+0.2	3.3	1:1.5	6.00	20 20	1.5mの上部工 基礎杭あり	△ 縦目地ずれ
D	+3.5	+0.0	3.5	1:1.5	6.00	20 20	1.5mの上部工 基礎杭あり	△ 縦目地ずれ
E	+5.3	+0.0	5.3	1:1.5	8.00	20 20	1.5mの上部工 基礎杭あり	× 縦横目地ずれ，ひらき
F	+4.0	+0.2	3.8	1:1.5	6.22	15 15	1.5mの上部工 基礎杭	○
G	+5.32	+0.2	5.12	1:1.7	10.10	25 (25)	1.7mの上部工 基礎杭	△
H	+5.22	+0.0	5.22	1:1.5 (1:1.9)	8.8 (9.5)	15 15	ブロック 0.75 二段積 1.00	×
I	+5.22	−0.5	5.72	1:1.5	9.5	15 15	1mの上部工 基礎杭	×
J	+5.20	−0.5	5.70	1:1.5	10.3	15 15	1mの上部工 基礎杭 (杭)	×
K	+5.22	+0.0	5.22	1:1.5 (1:1.9)	9.5 (10.0)	15 15	ブロック 1.00 二段積 1.00	×

Key:

1. Coastal Embankment
2. Crown Height
3. Bedding Anchor Height
4. Difference
5. Slope (Average)
6. Rear Spread
   Thickness
   Length Block Thickness
   m Road Base Thickness
7. Bedding Anchor
8. Foundation steel pile located in upper 2 m section
9. Foundation log located in upper 2 m section
10. Foundation post located in upper 1.5 m section
11. Foundation post located in upper 1.7 m section
12. Block 0.75
13. Double stack concrete 1.00
14. Foundation post located in upper 1 m section
15. Foundation post (depth) located in upper 1 m section
16. Block 1.00
17. Condition of Rear Spread
18. Aberration of vertical ground site
19. Aberration, break of vertical and horizontal ground sites

Table 6.2 can be regarded as a compilation and arrangement of the data on the external changes that were observed in embankments and the results of the weep hole investigations that were conducted (also external investigations of embankments).

Except for the Mitani fishing harbor sea wall, all the embankments that were investigated were self-supporting embankments with a fairly large rear spread. Most of them were located along the Koromoga and Mikawa Wan coastlines and were those whose construction had been more or less completed prior to the Ise Wan typhoon.

The discussions that follow are general comments by general categories on the external changes that were observed on these embankments.

Generally speaking, the foundation of these embankments was a reinforced bedding "choseki" /literally, "convered/spread rock/stone"; pell mell?/ of 200-300 kg, showing no scattering or erosion in the front. This condition could be attributed to the fact that these embankments for the most part are located way inside the bay where there is very little wave action. Most of the face spread armors were 50-cm thick concrete with no reinforcement and many covered over an old masonry coverings. They showed no structural breakdowns, such as cave-in, exposure, etc., and even the ground site was in fairly good condition with very little break and aberration. The breakdown that was observed was confined to the ground site decomposed piles (wooden piles) far removed from the spread edge to pose no immediate erosion danger to the embankment core. This kind of breakdown, needless to say, will require attention, perhaps not immediately but in time to prevent the development of embankment soil erosion which can lead to grave consequences.

Breaks and other breakdowns were observed along the worksite and in the corner angle section of these embankments. It cannot be determined whether they were the result of poor construction work or poor material used, but whatever the reason, the threat of soil erosion of the upper embankment was present in these embankments and some corrective measures will have to be instituted soon. Almost half of the embankments that were investigated were embankments that were structured with small-step/terrace face spread connected to the foundation (see Chart 6.6-6.9). The unique breakdown noted for these embankments was the cave-in that developed to the small-step/terrace concrete block of the crown. It is not known whether this was caused by the erosion of the embankment soil or by the sinking brought about by the consolidation of the insufficiently packed embankment soil below the small-step/terrace concrete block, but this kind of a breakdown can lead to serious chain breakdowns and thus, immediate action

must be instituted to repair the damage. This urgency will apply especially to those spots where wave action can be expected. Even if the cave-in cause was consolidation sinking, the inevitable results will be rain seepage, growing of grass, etc., to gradually weaken the whole structure.

The normal line direction cracks of the face spread armors were comparatively few in number. This was due, it is believed, to the armor thickness of about 50 cm, the relative lightness of the weight of the crown, and the mildness of the wave actions that occurred. Large numbers of normal line right angle direction cracks of the face spread armors, however, were observed with many that extended to the parapet. The uneven sinking of the embankment, it is believed, was the primary cause of these cracks. Comparatively small scale blister will not lead to a crack if the armor is very thick.

There was almost no indentation or soil erosion of the wave deflectors. An abrasion was detected in one spot but this appeared to have been caused by the use of poor concrete material. There was hardly any aberration or break at the ground site as well. The type of wave deflector damages that normally occur when the embankment base is soft and weak because of its location in a reclaimed land as shown in Photo 6.49 and 6.50 was not observed in the embankments investigated. Only few cases of wave deflector cracks were observed as well.

写真 - 6.49

Photo 6.49

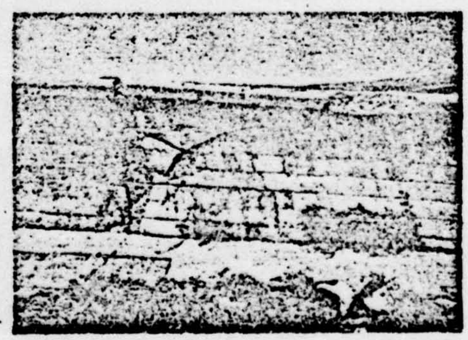

写真 - 6.50

Photo 6.50

Almost half of the embankments that were investigated had crowns with asphalt-concrete pavement. Hardly any crack or flaw was observed, moreover, in any of these crowns. The same, however, did not apply to those crowns with concrete pavement. They normally showed aberration or break at the joints with the rear spread armor or some normal line crack that usually extended along the center of the whole crown (see Photo 6.20). The latter development was especially true for those embankments with severely damaged rear spread armor. Concrete blocks are easily and directly affected by the soil erosion of embankment or by embankment shift. It can be assumed, therefore, that the appearance of a crack in the crown with concrete pavement is a positive indicator of its "rokyuka" [aging and growing uselessness].

With regard to rear spread armors, many breakdowns were observed. They included vertical aberrations and breaks at vertical and horizontal ground sites and even splits in mid-section. A comparison of the various rear spread armors was provided in Table 6.3. The primary causes of the splits mentioned above could be traced to the excessive length of the spread (normal spread slope is 1:1.5, and thus, the height of the crown is usually higher), the use of gravity type bedding anchor, too shallow bedding anchor foundation, and the use of thin 15-cm armor. Due to one or more of the above causes, the bedding anchor fell or tilted forward to provide an opening for the rain water to seep into the embankment to erode the embankment soil or to shift the embankment earth and soil to create holes and gaps which, in turn, developed cave-ins of armors (particularly thin armors) to develop the splits. From the above, it can be seen that the prevention of these splits will require not only the strengthening of the rear spread armors but the bedding anchors as well.

Discussed below are additional comments on the relationship between the changes in the embankment structures that had been discussed and the weep hole and air gap investigation that was conducted by the Aichi prefectural investigators.

As commented in a paragraph of the Aichi Prefecture Survey Report, many rice fields in this prefecture are rice fields that were developed as far back as the Edo period on reclaimed land along the coastline. The embankments that now stand were built, for the most part, to protect these rice fields. The rear area of every 1-5 km section of the embankments in this district is generally occupied by newly developed rice fields and generally speaking too, most of these embankments are quite similar in structure. In the weep hole and air gap investigation conducted by Aichi prefecture, two spots of this so-called "one embankment block section" [per text] were first selected (i.e., a spot with many cracks or a spot with very few cracks) and then the crown, face spread, and rear spread to remove their coverings to investigate the existence of any weep hole or air gap. The actual selection of these spots and the weep hole or air gap investigation

were left to the discretion of the local investigators. (It appears that in the selection of the structures to be investigated, those that showed breaks or cracks were eliminated or ignored.) Thus, the conclusion that can be reached is that although the site selection that was made did follow a certain established criteria, there was a certain degree of abstraction in the process employed.

In the study of the existence or non-existence and the number of weep holes and air gaps in embankments, it is well to remember that below every concrete armor, there normally is a rip-rap that contains air gaps (normal percentage is about 30% and the size of each gap could be fairly large as well), that the findings reached could vary greatly depending on how the coverings were removed and on the judgment of the individual investigator, and that in some cases, questionable conclusions could have been made. Thus, the statement in the aforementioned Aichi survey report that reads, "...in only 27 sites, or about 6.1% of the total..." should be revised to delete the word, "only," and replace it with, "at least," to read "...in at least 27 sites, or about 6.1% of the total..." After the investigation, fairly extensive repair work, such as injection of grout, etc., was undertaken by Aichi prefecture. This work covered not only those cracks where the weep holes and air gaps were discovered in the investigation but cracks in armors of embankments that were not covered in the investigation to support the contention made above.

In the Aichi survey report, the so-called weep hole and air gap were defined as those small openings of several centimeters and the main cause of these openings was attributed to the sinking that developed from the consolidation of the embankment soil. If this is true, it must be assumed that fairly widespread weep holes and air gaps are present near the base of every embankment as well. As explained before, the undertaking of investigation of hard-to-reach spots, such as the base area, is a difficult one to perform which mean, of course, that there could be many more spots where these small openings are present in an embankment. It is well known from the time of construction that widespread weep holes and air gaps can develop from developments, such as embankment sinking through soil shrinkage or consolidation, uneven sinking of embankment through imbalanced overhead weight, etc., but sad to say, the only reliable means available so far to determine the scale (depth and extent) of these weep holes and air gaps is the armor/covering removal method. The grout pouring repair method presently employed to seal these flaws, moreover, has not proved to be a foolproof method so far. That is to say, in addition to sealing the visible weep holes and air gaps, this process must eliminate the gaps that exist in the foundation rip-rap. So far, however, no means is available to accurately determine if the injected grout had fully sealed these rip-rap gaps. One advantage that may develop from this method is that if sufficient

grout is injected to cement the foundation concrete with the riprap, many of the smaller openings can be eliminated to greatly reduce the occurrence of erosive processes.

In the Aichi Survey Report, mention was made that in spots where weep holes were detected, cracks and aberrations of the joints connecting the rear spread armor and the crown were common occurrences. The existence of weep holes and air gaps in embankments that show no exterior crack or aberration in spreads or joints, however, cannot be detected by visual observation alone, the only exceptions being cases where there are obvious indicators such as soil erosion of embankments, etc. It is believed that there is no need to become too greatly concerned over the existence of these weep holes except in areas where strong wave actions and other severe external pressures against embankments are anticipated.

VII. Evaluation of Coastal Embankment Wasting Index and Methods of Coping with Breakdowns

An evaluation of the wasting index of coastal embankments was conducted by means (1) of employing certain selected breakdown process criteria and certain selected changes indicating wasting (wasting index) that have occurred to embankments since their construction and (2) of coordinating our on-the-spot investigation findings on the present conditions of the embankments with the investigation results published in the Aichi Survey Report.

The wasting indicators that showed on the surface of embankments served as the evaluation criteria in determining the extent of the wastings of coastal embankments. It was assumed that the breakdown of an embankment (wasting) occurs in gradual stages and that each stage of this breakdown designates some significant wasting index. The length span--i.e., from the time when wasting changes appear on an embankment surface to the danger point of the embankment collapse -- was categorized into A, B, and C stages. As employed, the "A" was used to designate the stage where the breakdowns have gone beyond the so-called "wasting stage" and where the embankment collapse is imminent unless the required repair work is performed immediately; the "B", the stage where the embankment breakdowns are in fairly serious "wasting" conditions and are in need of proper repair work to prevent the breakdowns from falling into the next serious category ("A"); and the "C", the stage where no visible embankment wasting can be detected from the surface but if changes begin to show, some repair work will be required. It should be noted that in the above, each symbol represents the assessed wasting value of an embankment or its structure from the changes that were observed from the exterior.

The wasting estimates by wasting index as mentioned above could be effectively employed, it is believed, in examining the existing wasting conditions of the coastal embankments from the standpoint of their structural designs and construction work and the maintenance and control work that have been performed. This wasting degree evaluation approach should not lead to any excessive estimation on the seriousness of the wastings; if the findings appear excessive and questionable, they should be weighed against the past neglect and lack of recognition on the seriousness of this problem on hand that have contributed to the underestimation of the embankment wastings. The reliability of this type of evaluation approach, needless to say, will depend largely on proper survey, research, practical testing of breakdowns, etc., that can be backed by comparative study and application of evaluation standards to the actual disaster damages that have occurred to embankments.

The wasting evaluation based on the wasting index can be used to assess a lone visible change (wasting) that appears on the surface of an embankment, but it is very seldom that this need arises. In most instances, the changes that surface are multiple ones that are interrelated. The wasting index can be employed to evaluate these changes to derive at some composite analysis of the problem on hand. In the table that follows, some of the measures that have been employed to cope with wastings have been included.

Wasting Index (Visible Changes That Appear Outside) and
Examples of Countermeasures Adopted Against Wastings

1 評価　A　堤防の被災状態であらわれる外見にあらわれる変化
（堤防の劣化の特定の段階を越えるかに越えた状態にあるとみなされるもので[illegible]）
B　堤防の劣化と強い関係を有する外見にあらわれる変化
C　堤防の劣化と弱い関係を有する外見にあらわれる変化

劣化指標（外見にあらわれる変化）とその対処工法の例

2 工種	3 劣化指標（外見にあらわれる変化）	4 評価	5 他に関連する劣化指標（外見にあらわれる変化）と対処工法の例 6 同時に生ずる劣化指標（外見にあらわれる変化）	7 対策（対処工法の例）
8 基礎工	[illegible]の洗掘 9	A	表のり被覆工：へこみ（折れ），目地のくいちがい 基礎工の打継目のずれ 法線直角方向のクラック 天端工：不陸と法線方向のクラック，施工目地の開き，陥没	基礎工前面に根付けコンクリート施工 堤体土の吸い出しがあり，堤体内に空洞があるため，空洞の規模に応じて，天端工，表のり被覆工を一部または全部はがし，堤体土の補給あるいはモルタル注入。 空洞の規模の確認にもとづいて工法選択
	根固捨石の移動，散乱 17	A		根固捨石の補給あるいは増強または突堤，離岸堤などの併設
	消波ブロックの移動，散乱，流出 19	A		消波ブロックの補給あるいは増強または突堤，離岸堤などの併設 前面土砂の補給，根固工の新増設，突堤，離岸堤の新増設，養浜
		A	基礎工基部が露出し 基礎工と表のりとの打継目に開き，ずれ，基礎工の不陸，はらみ出し 天端工の沈下あるいは法線方向のクラック	さらに基礎工前面に止水矢板等をうち，基礎工との間にコンクリートを充填，堤体土の吸い出しが予想されるため，グラウト注入，基礎工の補強（基礎工を厚くする，前面矢板工根付けコンクリートなど）
		B	表のり被覆にクラック	グラウト注入
	はらみ出し 29	A	洗掘，表のりとの打継目に開き	基礎工の支持力不足と考えられ，基礎工補強（基礎工を大きくする，前面矢板根付け）堤体土の吸い出しが予想されるためグラウト注入
	不陸 30	B		基礎の根入れ不足について，根入れ増加（矢板工など）
	コンクリート 摩耗，剥離 32	C		程度に応じて，根付けコンクリートなどを施工
	基礎矢板（止水用）の折れ穴あき 34	A		前面に矢板式，根付けコンクリート，グラウト注入
36 表のり被覆工	法線直角方向のはらみ出し 37	A	目地部の角欠け，開き，表のり面に法線直角方向のクラック 基礎工および根出し工との打継目にわずかなずれ，開き	堤防の不等沈下によるものと考えられる。空洞存在が予想されるのでグラウト注入 （施工不良によるものは特に対策必要なし）
	法線直角方向のはね出し 42	A	基礎工の欠かい，はね出し 表のり被覆目地の角欠け，開き，ずれ	表のり被覆の一部切取り，張替え，基礎工の増強 （このような場合，堤防は欠かいの状態，堤防全体の新設となるであろう）
	法線直角方向のへこみ 47	A	法線直角方向のクラック，折れ 前面洗掘，基礎工の破壊，表のり打継目の開き	堤体内に局部的に大きな空洞が生じたために表のりコンクリート版が折れた，あるいは版全体が沈下した場合であり，表のり被覆工の張替え（施工不良によるへこみは特に対策必要なし）
	材料 角が欠けている 53	B		他の変化によって起こされる，副次的な外見にあらわれる変化とみなされるが，規模が大きく，堤体土の吸い出し，が予想される場合は根付けコンクリートなどを施工
	摩耗 54	C		小規模であれば特に対策はいらない。ただ，不安感がある。 平面的でなく，版の端部から角欠けの状態になると，吸出しのおそれが生じてくるため対策が必要となる。
	損傷 57	C		小規模なものは問題はない。 大規模なものは場合場合で，補強の根付け等の工事が必要である。

② 工種	③ 劣化指標（外見にあらわれる変化）	④ 評価	⑤ 他に関する劣化指標（外見にあらわれる変化）と対策工法の例	
			⑥ 同時に生ずる劣化指標（外見にあらわれる変化）	⑦ 対策（対策工法の例）
60 表のり被覆工	61 表面のさび	C		62 ・鉄筋のかぶり不足あるいはコンクリートの劣化，鉄筋と鉄筋の腐食によってさびがにじみ出したもので，特に対策を必要としない（有効で簡易な対策なし）
	63 法線方向　目地の開き	A	64 ・基礎工の沈下，はらみ出し，表のり面のかん没	65 ・表のり被覆工の張替え，基礎工補強，周囲の表のりに空洞がある可能性が多く周辺部グラウト注入
	66 法線方向　目地の角欠け	B		67 ・施工不良（目地面がのり面に直角でなく，鋭角になるように施工した）あるいは材料の劣化，損傷が考えられるが，大規模なもののみ腹付けコンクリートなどの対策必要。
	68 法線方向　目地の上下ずれ	A	69 コンクリート版のかん没，はね出し基礎工の沈下，はらみ出し	70 ・のり被覆工の張替え，空洞が堤体内にあるため周辺部モルタル注入
	71 法線方向　目地の面内ずれ	A	72 （ほとんど起り得ないし，他に顕著な変化あり）	73 ほとんど起り得ない。起ったとしても，欠壊状態で他に顕著な変化があるので，判定は他の変化によって可能
	法線直角方向の目地の開き	B		75 施工不良，あるいは目地材の腐食その他による開きである場合，目地部にグラウト注入，周辺部にも堤体土の吸い出しがある可能性があるのでグラウト注入，特に陥没したコンクリート版にクラックがある場合はかなりの空洞があるものと考えられる。
		A	76 ・コンクリート版の陥没，目地の角欠け 77 基礎工あるいは根返し工の打継目に開き	79 表のり被覆工としての一体性が失なわれたもので，表のり被覆工の張り替えと基礎工の補強，周辺部に生じている空洞に対する処理としてグラウト注入工などが必要
	74 法線直角方向目地の角欠き	B		50 材料の劣化，施工不良による小規模な角欠けで，表のり被覆厚の1/3程度の深さで周辺部にクラックがなければ，現状では特に対策を必要としない。深さが被覆厚の1/3以上になれば腹付コンクリート工などが必要
		A	51 目地の開き，打継目の上下ずれ開き	52 被覆工の張り替えなどが必要
	53 法線直角方向目地の上下ずれ	B A		54 目地が合さっており，上下ずれが5cm以内で，目地の開き，版の折れなどを生じていなければ，十分のグラウト注入 ずれの程度が大きく，他に破壊を示すような顕著な変化があれば被覆工の張り替えが必要
	55 法線直角方向目地の面内ずれ	A		56 ほとんど起り得ないし，この変化がみられる時は，堤防は破壊の状態にあると考えられる。
	57 基礎工との打継目の開き	B	58 （表のり被覆工にクラックや目地のずれがない場合）	59 開きの程度とその状況によって，基礎工の移動が少なければ，のり先からの堤体土の吸い出しの程度を調べ，表のりにはグラウト注入，基礎工の打継目にもグラウト注入する。 基礎工の移動が大きければ，基礎工の補強と腹付けコンクリート工などが必要
		A	90 表のり被覆工にクラックや目地のずれ	91 目地のずれ，クラックの程度が小規模であれば基礎工の補強とグラウト注入 表のり被覆工の変化が顕著であれば，その変化に対して張替え等の対策をとる。
	92 基礎工との打継手の角欠け	B		93 材料の劣化，施工の不良によると推測され，その規模がかなりのもので，今後角欠けがさらに進行し，その部分から堤体土の吸い出しが予測されるなら，基礎工の補強，腹付けコンクリート工

工種	③ 劣化指標（外見にあらわれる変化）	② 評価	⑤ 他に関する劣化指標（外見にあらわれる変化）と対応工法の例	
			⑥ 同時に生ずる劣化指標（外見にあらわれる変化）	⑦ 対策（対応工法の例）
90 表のり被覆工	基礎工との打継手の上下ずれ 94	B	（表のり小段の場合）95	96 小段の水平な被覆工がずれている場合，グラウト注入で基礎待石との一体性を増す。
		A	97 [illegible]返し工，との打継目にずれあるいは開き	97a 基礎工の抵抗不足によって，表のり被覆工を支持し得ないからで基礎工の補強と共に，表のり下面にグラウト注入すると共に決きも埋る。
	98 [illegible]返し工との打継目の開き	A	99 基礎工との打継手の上下ずれ	100 以上の対策をとる。
		A	101 [illegible]返し工の破損，又は工の[illegible]返し工近くにクラック	102 [illegible]返し工が自重あるいは土圧によって破損したもので[illegible]返し工に基礎ぐいの補強をし，又は工の打替えあるいはグラウト注入などが必要。
	103 [illegible]返し工との打継手のずれ	A		104 一般的な構造では[illegible]返し工と表のり工は水平な打継目を有しているため，ずれは[illegible]返し工に強い土圧が作用したため生じたものと考えられるが，このためずれだけにとどまらず，[illegible]返し工の破損，打継目の開きあるいは転倒を生じている。
	105 [illegible]返し工との打継手の角欠け	C		106 [illegible]返し工の剥離による場合も考えられるが，このような場合は少ない。 材料の摩耗，損傷の場合，小規模である場合，特に対策必要なし
	107 法線方向のクラック	B		108 [illegible]返し工が過大，又は重交通が通行する場合，基礎工が支持力不足などの場合が考えられ，他の変化とも組み合せ総合的に原因を推定し対策をたてるが，数が少なければ，グラウト注入 数が多くて，被覆工の一体性に疑問をもてば，表のりの張付け，張替え。
	109 法線直角方向のクラック	B		110 堤体の不等沈下，堤体内に空洞が生じたためと考えられるが，数が少なければグラウト注入，数が多ければ，基礎工からの堤体土の吸い出し等の検討とともに表のりの張付け，張替え
112 [illegible]返し工	[illegible]返し工の不陸 113	B		115 堤防の不等沈下によるもので，他に色々な変化がみられるから，それによって対策をたてる。
		C	特になし 114	116 施工不良によるものと考えられる，特に対策必要なし
	[illegible]返し工法線の出入り 116	C	特になし 114	117 施工不良によるものと考えられる，特に対策必要なし
		A	118 [illegible]返し工の前，後傾又は工および表のり工との打継目のずれ	119 表の作用等の外力や[illegible]返し工の自重によって変形したもので，表のり被覆工の場合同
	材料の角欠け 120	C		121 特に対策なし
	材料の摩耗 122	C		123 特に対策なし，美観を問題とするならモルタル吹付け
	材料の損傷 124	C		125 特に対策なし，損傷が大きければ打ち替え
	目地の者さび 126	B		127 モルタル吹付け，強大な外力が作用する箇所では張付けも考慮する

工種 (2)	(3) 劣化指標 (外見にあらわれる変化)	評価 (4)	(5) 堤に関する劣化指標(外見にあらわれる変化)と対処工法の例	
			(6) 同時に生ずる劣化指標(外見にあらわれる変化)	(7) 対策(対処工法の例)
(111) 胴込し工	目地開き (128)	B		(129) 堤防の不等沈下によるもので、防潮機能を特に期待されていなければ、放置しておくかあるいはグラウト注入
		B	(130) 胴込し工の目地の上下ずれ、天ば工の目地の開き法線直角方向クラック、裏のりクラック。	(131) 周辺部に堤体の空洞が生じている。グラウト注入
	目地の上下ずれ (132)	B	(133) 天ば工、裏のりと目地にずれや開き。 (135) 天ば工にクラック、胴込し工目地の開き。	(134) 堤防の不等沈下によるもの、周辺に空洞の発生が予想されるためグラウト注入 (136)（施工不良による場合もある）
	目地の前後ずれ (137)	B	(138) 裏のり、天ば工との目地目に開きずれ、角欠け、天ば工にクラック	(139) 強い波力の作用か堤体の不等沈下、空洞があると考えられ、グラウト注入
	法線直角方向のクラック (140)	B	(141) 目地、クラックに開き、裏のりに連続してクラック (143) 胴込し工のみにクラック（開きなし）	(142) 堤防の不等沈下によるもので、グラウト注入 (144) 1スパンに1本程度であれば、特に対策必要なし
	法線方向水平クラック (145)	B		(146) 鉄筋が入っておれば、はげしい不等沈下後の作用以外に原因は考えられないが強力な波力が作用する場合は補強が必要 不等沈下によるものと考えられる箇所では、空洞の発生が予想されるので他の変化によって判断し対策をたてる。
(147) 天ば工	不陸 (148)	C	(149) 法線直角方向のクラックがほとんどない。	(150) 施工不良によるものであるかあるいは、堤防の不等沈下はあったが、空洞の発生がほとどなかった場合で、特に対策必要なし
		B	(151) 法線直角方向のクラックが多く、法線方向のクラックもある	(152) 堤体内の空洞の存在が予想され、グラウト注入
		A	(153) 天ばコンクリート版の折れ、沈下、裏のり工、胴込し工との目地目にずれあるいは開き。	(154) 堤体内の空洞がかなり大規模で、裏のり被覆工にも欠陥があるものと予想され、被覆工、裏のり工の改良をも含めた対策が必要、グラウト注入、打替え、被覆補強
	材料の角欠け (155)	B	周辺にクラック (156)	(157) 自動車の通行によって隅角部に角欠けが生じたものであり、堤体内への雨水や越波の浸透を促進させるため、アスコン補修などが必要 自動車の通行のない箇所ではほとんどないものと考えられる。
	材料の摩耗 (158)	B		(159) 交通量の少ない箇所では対策必要ない。しかし天ば工に摩耗箇所があらわれるようでは相当に施工や材料が不良であるとみなされ、他に欠陥がみられると考えられる。
	材料の損傷 (160)	B	周辺のクラック (161)	(162) 重交通によるものと考えられるが、クラックが生じ、コンクリート版の一体性が失なわれているため、場合によっては、打替えも考慮
	施工目地の開き (163)	B B	(164) 天ば工にクラック 胴込し工にクラック、裏のり被覆にクラック	(165) 雨水や越波水の浸透によって堤体上の影響をおこすため、目地をふさぐとともに、グラウト注入 空洞が存在するためグラウト注入

工種 (2)	(3) 劣化損傷 (外見にあらわれる変化)	判定 (4)	(5) 他に関する劣化損傷（外見にあらわれる変化）と対策工法の例: (6) 同時に生ずる劣化損傷（外見にあらわれる変化）	(7) 対策（対策工法の例）
天ば工 (147)	施工目地の上下ずれ (166)	B	付近の面にクラック	空洞の存在が予想されグラウト注入
	施工目地の左右ずれ (169)			（ほとんど考えられない）
	施工目地の角欠け (171)	B	目地にクラック (172)	（材料の角欠けの程度）
	波返し工との打継目の開き (174)	B		一般には、天ば工の沈下の場合であり、この場合、天ば工と波返し、表のり工との一体性は失なわれ、空洞の生じていることが多いためグラウト注入。
		A	基礎工のはらみ、沈下 (176)	基礎工のはらみ出し、沈下などによって表のり工がすべり波返し工が前にのめった場合も考えられるがこの場合は表のり被覆工の補修
	波返し工との打継目の上下ずれ (170)	B	(177) 天ば工にクラック、折れ、表のり工との打継目にずれ、開き	天ば工の沈下による場合が多く、この場合天ば工と波返し工、表のり工との一体性は失なわれ、空洞の生じていることが多いためグラウト注入 天ば工の破損が著しい場合は打替え
	波返し工との打継目の角欠け (151)	B		波返し工の破損によるもので、波返し工の破損によって判断を下すべきである。
	表のり工との打継目の開き (183)	A	(184) 根留工のはらみ出し、表のり面のはらみ出し、表のり目地の上下ずれ、のり面の折れ	根留工の抵抗不足によるものと考えられ、根留工の抵抗を補強するとともに表のり面の破損の程度に応じて、のり面の一部張替え、グラウト注入
	表のり工との打継目の上下ずれ (186)	A	(187) 根留工のはらみ出し、表のり面のはらみ出し、表のり面のクラック	打継目の開きに先立っても生ずるが、この場合は堤防としての一体性はかろうじて保たれていると考えられ、根留工の補強とともに、表のり下面に空隙が生じていることが予想されるのでグラウト注入 施工時に天ば工の上端を表のり面の上端よりも高く施工されることもあるので判断には注意を要する。
	表のり工との打継目の角欠け (190)	B		ほとんど生じないが、重車輌の通行によって生じた場合は、その箇所を直ちに補修するとともに、その周辺に空洞が生じていればグラウト注入
	法線直方向のクラック (192)	B		このクラックのみで少ない場合、空洞の存在は予想されるのでグラウト注入が望ましい。多い場合、空洞が存在するのでグラウトを注入 重車輌は一般の堤防上を通行することは望ましくなく、重車輌によってクラックが生じた場合、根留工のはらみなどについても注意する必要がある。
	法線方向のクラック (194)	A	(195) 根留工のはらみ出し、表のり面のはらみ出し、表のり被覆の破損	表のり面が破損したために入ったクラックである。このため根留工の補強 表のり面の改修のあと、クラックの程度に応じて張替えあるいはグラウト注入
表のり被覆工 (147)	法線直角方向のはらみ出し (193)	A	天ば工との打継目に上下ずれ、法線直角方向のクラック	表のり被覆工が相対的に弱い（うすい）ためであり、時間の経過とともに目地に開きやずれなどを生じる。このため、表のり面にグラウトを注入し、被覆工を強化するか張りコンクリート工。 施工不良の場合もあり

②	③ 変化種類（外見にあらわれる変化）	評価 ④	⑤ 他に関する変化種類（外見にあらわれる変化）と対策工法の例	
			⑥ 同時に生ずる変化種類（外見にあらわれる変化）	⑦ 対策（対策工法の例）
197	法線直角方向のはらみ出し 201	A	被覆工のはらみ出し 202	203 被覆工がはらみだしたため、裏のり先が土圧に抵抗しきれなくなってはらみ出したもので、被覆工の補強および裏のり部の打替えあるいは裏付け
[illegible]	法線直角方向のへこみ 204	A	のり面の折れ、目地の開き上下ずれ 205	206 のり面下に大きな空洞が生じたため裏のりコンクリート版が落ち込んだためである。のり面の打替えあるいはグラウト注入
			のり肩にクラック 207	208 施工不良の場合もある。
	材料の角欠け 209	C		210 ほとんどないと考えられる。
の	材料の摩耗 211	C		212 摩耗のはげしいところ以外は特に問題ないが、被覆厚が薄い場合は裏のり面の強度として問題がある。モルタル吹付け、グラウト注入
	材料の風化 213	C		214 ほとんど例はない。事例の調査要
り	表面のあばた 215	C		216 裏のり被覆工には鉄筋は一般に入っていないが枠工などの場合はモルタル吹付けなどを行なう。
	法線方向目地の開き 217	A	被覆工のはらみ出し 218	219 被覆工を補強し、のり面の状態に応じてグラウト注入、裏付けコンクリート
[illegible]	法線方向目地の上下ずれ 220	A	被覆工のはらみ出し 221	222 被覆工を補強し、のり面の状態に応じてグラウト注入裏付けコンクリート
	法線方向目地の面内ずれ 223			224（このような場合は他二つの変化で判定する）
[illegible]	法線方向目地の角欠け 225	C		226 ほとんど例なし、小規模なものは対策必要なし
工	法線直角方向目地の開き 227	B	法線直角方向クラック、折れ 228	229 のり面下に空洞が生じ、のり面が折れたためで、折れの程度、すなわち空洞の規模に応じて、グラウト注入かのり面の打替え
		A	被覆工のはらみ出し 230	231 のり面の打替え、周辺部グラウト注入
	法線直角方向目地の上下ずれ 232	B	法線直角方向クラック 233	234 グラウト注入
	法線直角方向目地の面内ずれ 235	C		236 ほとんど例なし
	法線直角方向目地の角欠け 237	C		238 ほとんど例なし
	基礎工との打継手の開き 239	B	天端工との打継手の上下ずれ、クラック 240	241 軽微であれば、のり先にグラウト注入被覆工補強、それ以上の場合は矢板裏付けコンクリートなどで補強 裏のり下部にグラウト注入
	基礎工との打継手の上下ずれ 242	B	基礎工との打継手の開き 243	244 打継手の開きの調査要
	法線方向のクラック 245	B	被覆工のはらみ出し 246	247 被覆工の補強、クラックの程度に応じ、開きを生じていなければモルタル注入、開きのある場合は被覆工の打替えも考慮する
	法線直角方向のクラック 248	B		249 クラックが多ければ被覆工の打替えも考慮するが、空洞対策のグラウト注入

② 工種	③ 変化現象（外見にあらわれる変化）	評価 ④	⑤ 他に関する変化現象（外見にあらわれる変化）と対策工法の例 ⑥ 同時に生ずる変化現象（外見にあらわれる変化）	⑦ 対策（対策工法の例）
	法線直角方向のはらみ出し 250 はね出し 251	A	25_ 天ば工の法線方向クラック、天ば工と裏のり工の打継手に開き、上下ずれ。 25_ 裏のりにクラック、目地の開き、折れ	25_ 抵抗力不足によるもので、矢板や杭などによって根入れを大きくするとともに断面を大きくする。裏のり工は、状況の程度に応じ、張替え、グラウト注入
	法線方向の不陸 253	B	257 天ば工と裏のり工の打継手の上下ずれ 裏のり工との打継手の上下ずれ	257 根留工が特に軟弱な箇所等で矢板やくいの根入れ不足によって不等沈下したもの。根留工の補強とともに、上下ずれの程度に応じて、グラウト注入
	施工目地の開き 258	B'	25_ 根留工のはらみ出し	2_ 法線方向の不陸（はらみ出し）参照
	施工目地の上下ずれ 267	B	2_ 裏のり工との打継手にずれ、裏のり工にクラック目地の開き	2_ 法線方向の不陸参照
	施工目地の前後ずれ 264	B	26_ 裏のり工との打継手にずれ、裏のり工にクラック目地の開き	2_ 根留工頭部の結合力不足、頭部の補強

Key (to Tables on pages 129-135)

1. Evaluation:
   A = Visible changes showing disaster damage condition of embankment (embankment wastings far beyond "wasting" stage and embankment facing imminent collapse; immediate repair and restoration work required.

   B = Visible changes showing very serious embankment wastings.

   C = No serious visible wasting change in embankment
2. Type of Structure
3. Wasting Index (Changes That Can Be Seen From the Exterior)
4. Evaluation
5. Other Interrelated Wasting Index (Changes That Can Be Seen From the Exterior) and Examples of Countermeasures Adopted Against Wastings
6. Wasting Index That Develops At the Same Time (Changes That Can Be Seen From the Exterior)
7. Countermeasures (Examples of Measures Employed to Cope with Wastings)
8. Foundation
9. Destruction of joint section with rock base
10. Face spread armor: cave-in (break), disparity with ground site
11. Aberration of pile joint of foundation
12. Normal line right angle direction crack
13. Crown: soil erosion and normal line direction crack, break and cave-in at work site
14. Concrete work to cover the front of foundation
15. Removal of part or whole crown and face spread armor depending on the size of the weep holes and cavities that develop within the embankment to cause soil erosion so as to replace the eroded soil or to pour in mortar to fill the vacuum.
16. Selection of proper repair work based on the weep hole scale found
17. Scattering, burial of reinforced bedding spread rocks
18. Replacement of reinforced bedding rocks, or further restrengthening of bedding; also construction of additional facilities, such as breakwater, off-shore levee, etc.
19. Erosion, scattering, burial of precast concrete armor
20. Replacement or reinforcement of precast concrete armor, or construction of additional facilities, such as breakwater, off-shore levee, etc.
21. Replacement of earth and sand in the front; construction of stronger reinforced bedding, or breakwater, levee, and man-made beach
22. Exposure of ground base of foundation
23. Installation of still-water sheet piles in front of the foundation and filling up the in-between space with concrete; against possible development of embankment soil erosion, pouring in grout; reinforcement of foundation (via deeper foundation base, concrete pouring in front of the sheet piles, etc.)

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24. Break, aberration at pile joint between foundation and face spread
25. Crack in face spread armor
26. Pouring in of grout
27. Exposure
28. Erosion; break at pile joint with face spread armor
29. Cause attributable to insufficient support of foundation; re-strengthening of foundation (via enlargement of foundation, installation of sheet piles in the front)
30. Soil erosion
31. Insufficient depth of foundation; deeper foundation base (also installation of steel piles)
32. Damage, abrasion of concrete
33. Undertaking of required concrete addition after determination of need
34. Break and development of holes in foundation steel piles (use for still-water)
35. Conversion of the front into steel pile structure; augmentation by concrete; pouring in of grout
36. Face spread armor
37. Normal line right angle direction exposure
38. Break and angular break at ground site; normal line right angle direction crack in face spread surface
39. Break and slight aberration between pile joint and foundation as well as wave deflector
40. Cause attributable to uneven sinking of foundation; against possible development of weep holes, pouring in of grout
41. (No special countermeasure required for poorly undertaken work)
42. Normal line right angle direction break-up
43. Break and break-up of foundation
44. Angular break, break, and aberration of face spread at ground site
45. Removal of a portion of face spread armor and recovering; reinforcement of foundation
46. (In this kind of case, embankment normally in a state of near collapse requiring construction of a completely new embankment)
47. Normal line right angle direction indentation
48. Normal line right angle direction crack and break
49. Erosion of front, destruction of foundation, break in face spread pile joint

50., 51. Case where the development of large air holes in a section within the embankment caused the break in the face spread concrete block or the sinking of the whole block; recovering of face spread armor (no special countermeasure required for indentation caused by poorly undertaken work)

52. Angular break in material
53. Breakdown caused by some other change; most probably visible secondary change (wasting), but if break large to cause embankment soil erosion, will require repair work, such as recovering by concrete, etc.
54. Abrasion
55. If minor, no special countermeasure required; this recommendation given with certain reservation
56. If not on flat area but at edge of block and then right angle, could lead to erosion; in this case, countermeasure will be required.

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57. Damage
58. No problem if damage minor
59. If a major damage, then repair work such as reinforcement, re-covering, etc., will be necessary.
60. Face Spread Armor
61. Surface rusting
62. Rusting caused by insufficient covering of ferro-concrete, abrasion and damage to concrete, or erosion of iron bars; special countermeasure not required (no easy and effective countermeasure available)
63. Normal line direction break at ground site
64. Sinking, exposure of foundation; cave-in of face spread surface
65. Replacement of face spread armor; repair of foundation; possible existence of weep holes under face spread, requiring injection of grout
66. Normal line direction angular break at ground site
67. Possibly caused by poor construction work (no right angle alignment of ground site surface with face spread), or abrasion or damage of material; if a major break, will require repair work, such as concrete recovering and other countermeasures.
68. Normal line direction vertical aberration at ground site
69. Cave-in, cracking of concrete blocks; sinking and exposure of foundation
70. Recovering of spread armor; presumed existence of weep holes in embankment, requiring injection of mortar in surrounding areas
71. Normal line direction aberration beneath the surface of ground site
72. (A very rare occurrence; presence of other conspicuous changes)
73. Very rare occurrence; if it happens, embankment on verge of collapse and other conspicuous changes (wastings) should be observable; main cause could be determined by analyzing other wastings.
74. Normal line right angle direction break at ground site
75. Most probable cause: poor construction work or erosion of ground site blocks; if break caused by some other factors, injection of grout in ground site section necessary--possibly in adjacent areas as well if soil erosion in embankment suspected; if cracks in adjacent area blocks, assume existence of many weep holes in the whole area.
76. Cave-in of concrete blocks; angular break at ground site
77. Break in pile joint of foundation or wave deflector
78. Means destruction of the single unit feature of face spread armor; will require recovering of face spread armor and reinforcement of foundation; injection of grout for weep hole development in area will be necessary.
79. Normal line right angle direction angular break at ground site
80. Normally minor scale angular break caused by poor construction work or material abrasion; if cracks in surrounding areas no deeper than 1/3 the thickness of face spread armor, no special countermeasure necessary; if depth more than ½ the thickness, then concrete covering work, etc., necessary.

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81. Break at ground site; break and vertical aberration at ground site
82. Required repair work such as replacement of armor
83. Normal line right angle direction vertical aberration at ground site
84. If ground site shows no break and no irregularity and if no block break and 5 cm or less aberration, only action required is injection of sufficient grout; if a major aberration and if other conspicuous changes showing breakdown in view, replacement of armor will be required.
85. Normal line right angle direction aberration beneath ground site
86. Very rare occurrence; its occurrence most probably means near collapse condition of embankment
87. Break of pile joint with foundation
88. (Cases where there is no crack in face spread armor and where there is no aberration at the ground site)
89. Depending on degree of break and cause and if only a minor foundation shift, inject grout from top of face spread after checking for embankment soil erosion near end of spread; inject grout into pile joint of foundation as well; if a major foundation shift, repair, such as reinforcement of foundation, recovering with concrete, will be required.
90. Crack in face spread armor and aberration at ground site
91. If ground site aberration and crack only minor scale, repair by reinforcing foundation and injecting grout; if change in face spread armor very conspicuous, then based on the change, countermeasures such as replacement of coverings, etc., will be necessary
92. Angular break of pile joint with foundation
93. Possible cause: material abrasion or poor construction work; if break fairly big and indicates possibility of getting bigger and possible development of embankment soil erosion, reinforce foundation and carry out concrete recovering work.
94. Vertical aberration of pile joint with foundation
95. (In case of small step/layer of face spread)
96. In case of the aberration of the level coverings of small step/layer, inject grout to improve the binding of rip-rap with foundation to set up one-piece structure of the two
97. Break or aberration of pile joint with wave deflector
97a. Cause is inadequate resistance capability of foundation to support face spread armor; reinforce foundation and at the same time, inject grout beneath the face spread to seal up the break.
98. Break between pile joint and wave deflector

(Continued <u>Key</u> to Tables on pages 129-135)

99. Vertical aberration between pile joint and foundation
100. Same countermeasures as listed in <u>97a</u> above
101. Backward tilting of wave deflector; crack in crown near the wave deflector
102. Backward tilting caused by wave deflector own weight or by wave force; reinforce wave deflector binding with foundation: replacement of crown top and injection of grout may also be necessary
103. Aberration of pile joint with wave deflector
104. In most embankments, pile joint for wave deflector and face spread located at water level, and thus, aberration believed to have been caused by strong wave action against wave deflector; wastings not confined to aberration alone but should include backward tilting of wave deflector, break of pile joint, and also toppling.
105. Angular break of pile joint with wave deflector
106. Forward tilting of wave deflector could happen, but this would be rare case; if caused by abrasion of material, minor damage, and if angular break minor, no special countermeasure not required.
107. Normal line direction crack
108. Causes could be: excessive size of wave deflector, excessive traffic use of crown, and inadequate support capability of foundation; countermeasures to be coordinated with repair work on other changes after determining the cause; if number of cracks small, inject grout.
109. Normal line right angle direction crack
110. Causes believed to be uneven sinking of embankment core and development of weep holes in embankment; if number of cracks small, inject grout; if number, great many then examine embankment soil erosion around foundation and undertake repair work, such as recovering of face spread or replacing old armor with new armor.
111. Wave deflector
112. Soil erosion of wave deflector
113. Cause: uneven sinking of embankment; many other changes will also surface so countermeasures to be employed to be based on assessment of the causes of these changes.
114. Nothing special
115. Cause believed to be poor construction work; no special countermeasure necessary
116. Normal line indentation of wave deflector
117. Cause believed to be poor construction work; no special countermeasure necessary
118. Forward or backward tilting of wave deflector; aberration between pile joint and crown
119. Cause of transformation: wave action or from own weight of wave deflector; for countermeasures, refer to face spread armor section of the table

(Continued Key to Tables on pages 129-135)

120. Angular break of materials
121. No special countermeasure available
122. Abrasion of materials
123. No special countermeasure available; if appearance is the primary concern, spray on mortar.
124. Damage to materials
125. No special countermeasure available; if a major damage, replacement only solution
126. Surface rusting
127. Spray on mortar; if exposed to strong wave action, recovering may be considered
128. Break at ground site
129. Cause: uneven sinking of embankment; if no special protection required against tides, no action required except possible injection of grout
130. Vertical aberration of wave deflector; break of crown at the ground site and normal line right angle direction crack; crack of face spread
131. Development of weep holes in and around the adjacent areas in embankment; injection of grout
132. Vertical aberration at ground site
133. Break in top of crown and break and aberration between pile joint and face spread
134. Cause: uneven sinking of embankment; most probable development of weep holes in the area; grout injection
135. Crack in crown; break in wave deflector at ground site
136. (One of the causes could be poor construction work)
137. Aberration of ground site--both front and back
138. Break and aberration of pile joint with face spread and crown--also angular break; crack in crown
139. Cause: uneven sinking of embankment caused by strong wave action; possible development of weep holes; injection of grout
140. Normal line right angle direction crack
141. Crack and break at ground site; crack extending to face spread
142. Caused by uneven sinking of embankment; injection of grout
143. Crack in wave deflector only (no break)
144. If a single line crack in a span, no special countermeasure required
145. Normal line direction water level crack
146. If a ferro-concrete structure, a serious uneven sinking caused by wave action; strong wave action site will require reinforcement of wave deflector
If cause suspected to be uneven sinking, existence of weep holes most probable; countermeasures should be based on assessment of other changes as well
147. Crown
148. Soil erosion
149. Rare to find normal line right angle direction crack
150. Cause: poor construction work or uneven sinking of embankment; uneven sinking noted but very few weep holes found; no special countermeasure required
151. Many normal line right angle direction cracks; also some normal line direction cracks
152. Existence of weep holes in embankment most probable; injection of grout

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153. Sinking, break in crown concrete blocks; aberration or break in pile joint with rear spread and wave deflector
154. Most probable existence of large size weep holes in embankment and also cave-in of rear spread bedding anchor; required repair work includes improvement of bedding anchor and rear spread as well as injection of grout and also possible replacement of pile joint and strengthening of bedding anchor
155. Angular break of materials
156. Cracks in surrounding areas
157. Angular break located in the corner angle section caused by heavy traffic; major problem: increasing permeation of rain water and overtopping waves into embankment: required repair work includes resurfacing by asphalt-concrete
158. Abrasion of materials
159. No countermeasure required for crowns used by light traffic, but if more and more material abrasion spots appear on crown, due attention should be given for possible development of cave-ins and other breakdowns; primary cause of this abrasion: poor construction work or use of poor quality materials
160. Damage to materials
161. Cracks in surrounding areas
162. Primary cause believed to be excessive heavy traffic; the development of cracks means destruction of concrete block solidity, possibly requiring replacement of the whole concrete block
163. Break at the work and ground sites
164. Crack in crown
     Crack in wave deflector; crack in rear spread armor
165. Injection of grout and re-covering of the ground site to prevent the shifting of embankment soil from penetrating rain water and overtopping waves
166. Vertical aberration of work and ground sites
167. Cracks in near-by blocks
168. Probable existence of weep holes; injection of grout
169. Aberration beneath the surface of work and ground sites
170. (Very rare case)
171. Angular break at work and ground sites
172. Cracks in surrounding areas
173. (See angular break of materials section in this table)
174. Break between pile joint and wave deflector
175. General cause: sinking of crown; this development normally leads to the solidarity break-up of crown, wave deflector, and rear spread and to weep holes in the embankment; injection of grout for repair work
176. Exposure and sinking of foundation
177. Exposure and sinking of foundation could lead to face spread sliding and forward tilting of wave deflector; for countermeasure, see face spread column in this table
178. Vertical aberration of pile joint with wave deflector

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179. Crack and break in crown; break and aberration of pile joint with rear spread
180. In most cases, main cause is the sinking of crown; this development destroys the solidarity of crown, wave deflector, and rear spread and leads to weep holes in the embankment; countermeasure: injection of grout
181. Angular break of pile joint with wave deflector
182. Cause: backward tilting of wave deflector; countermeasure: should be based on assessment of backward tilting situation
183. Break in pile joint with rear spread
184. Exposure of bedding anchor; exposure of rear spread armor; vertical aberration of rear spread at ground site; break in spread surface
185. Believed main cause due to inadequate resistance capability of bedding anchor; countermeasures: reinforcement of bedding anchor resistance capability; based on the extent of damage to rear spread armor, replace required armor parts; injection of grout
186. Vertical aberration of pile joint with rear spread
187. Exposure of bedding anchor; exposure of rear spread armor; crack in rear spread armor
188. This breakdown can also occur from pile joint break, but in this particular case (referenced vertical aberration), the solidarity of embankment believed to be still intact although barely; required countermeasures: reinforcement of bedding anchor; injection of grout because of probable development of air gaps beneath the rear spread
189. In some cases, the height of the upper edge of crown has been made higher than the upper edge of rear spread and thus, due attention must be given to this fact in assessing the countermeasure to be adopted.
190. Angular break of pile joint with rear spread
191. Rare occurrence; if it does, immediate repair at the break site must be undertaken; inject grout if weep holes developed in surrounding areas.
192. Normal line parallel direction crack
193. If only small number of cracks, grout injection should be undertaken against possible development of internal air gaps as preventive measure; if large number of cracks, grout injection would be a prerequisite since the existence of air gaps is a certainty.
194. Normal line direction crack
195. Exposure of bedding anchor; exposure of rear spread armor; damage to rear spread armor
196. Crack due to rear spread armor damage; reinforce bedding anchor; after repairing rear spread armor, recheck extent of crack for injection of grout or for possible need to replace the bedding anchor

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197. Rear spread armor
198. Normal line right angle direction exposure
199. Vertical aberration of pile joint with crown; normal line right angle crack
200. Primary cause: relative weakness (thinness) of rear spread armor leading to break and aberration at the ground site after passing of time; repair work includes injection of grout beneath the spread, reinforcement of the armor, or possibly recovering by cement
    Breakdown cause could be poor construction work.
201. Normal line right angle direction cracking and exposure
202. Exposure of bedding anchor
203. Cause: inability of rear spread edge to resist earth pressure as a result of the exposure of bedding anchor; countermeasure: reinforcement of bedding anchor, replacement of rear spread armor or recovering the whole armor
204. Normal line right angle direction indentation
205. Break in spread surface; vertical aberration and break at ground site
206. Cause: cave-in of rear spread concrete block as a result of the development of weep holes beneath the rear spread armor; countermeasure: replacement of whole spread armor or injection of grout
207. Spread surface crack
208. Cause: poor construction work has been the reason at times.
209. Angular break of material
210. Believe this is rare case.
211. Abrasion of material
212. No serious problem except at sites where heavy overtopping waves occur; if the rear spread armor is too thin, the problem may occur; countermeasures: spraying of mortar, injection of grout
213. Damage to material
214. A very rare case; see abrasion column of this table
215. Surface rusting
216. All rear spread armors are not ferro-concrete; if rusting of framework, spray mortar
217. Normal line direction break at ground site
218. Exposure of bedding anchor
219. Countermeasures: reinforcement of bedding anchor; depending on spread surface condition, injection of grout or recovering with concrete
220. Normal line direction aberration at ground site
221. Exposure of bedding anchor
222. Countermeasures: reinforcement of bedding anchor; depending on spread surface condition, injection of grout; possibly require recovering with concrete
223. Normal line direction aberration beneath the ground site
224. (in a case of this kind, estimation to be made by two previous changes /sic; not further explained/

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225. Normal line direction angular break at ground site
226. Very rare case; if minor break, no countermeasure necessary
227. Normal line right angle direction break at ground site
228. Normal line right angle direction break and crack
229. Cause: breaking of spread surface as a result of weep hole development beneath the spread surface; repair work includes injection of grout or replacement of spread armor, depending on degree of break and largeness of weep hole area
230. Exposure of bedding anchor
231. Countermeasures: replacement of spread armor and injection of grout in the surrounding areas
232. Normal line right angle direction vertical aberration at the ground site
233. Normal line right angle direction crack
234. Countermeasure: injection of grout
235. Normal line right angle direction aberration beneath the surface of ground site
236. Very rare case
237. Normal line right angle direction angular break at ground site
238. Very rare case
239. Break between pile joint and bedding anchor
240. Vertical aberration and crack of pile joint with crown
241. If only several cm break, only required repair would be injection of grout and reinforcement of bedding anchor; if break bigger, then installation of steel piles, reinforcement by concrete, and injection of grout beneath the rear spread armor
242. Vertical aberration of pile joint with bedding anchor
243. Break of pile joint with bedding anchor
244. See section dealing with pile joint break in this table for countermeasure
245. Normal line direction crack
246. Exposure of bedding anchor
247. Countermeasures: reinforcement of bedding anchor; based on degree of crack and if no break, inject mortar, but if break evident, might require replacement of whole armor
248. Normal line right angle direction crack
249. Countermeasures: if many cracks, may require replacement of covering; injection of grout for weep holes
250. Normal line right angle direction exposure
251. Cracking and exposure
252. Normal line direction crack of crown; break and vertical aberration of pile joint with crown and rear spread
253. Cause: inadequate horizontal resistance capability; countermeasures: expand and strengthen the bedding by installing steel piles and posts and also enlarge the whole section; based on the extent of damage, the repair work of rear spread could be grout injection or replacement of the armor

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254. Rear spread crack; break, cracking at ground site
255. Normal line direction soil erosion
256. Vertical aberration of pile joint with crown and rear spread
Vertical aberration of pile joint with rear spread
257. Cause: uneven sinking due to too shallow implacement of steel piles and posts and soft and weak base of bedding anchor; countermeasures: reinforcement of bedding anchor and depending upon the degree of vertical aberration, injection of grout
258. Break at work and ground sites
259. Exposure of bedding anchor
260. For countermeasure, see column dealing with normal line direction soil erosion in this table (exposure)
261. Vertical aberration at work and ground sites
262. Aberration of pile joint with rear spread; break of rear spread crack at ground site
263. For countermeasure, see column dealing with normal line direction soil erosion in this table
264. Aberration beneath the work and ground sites
265. Aberration of pile joint with rear spread; break of rear spread crack at ground site
266. Cause: insufficient binding power of bedding anchor head/top section; countermeasure: reinforcement of head/top section.

VIII. On the Designing and Construction of Coastal Embankments

Two or three matters that deserve very careful attention in the designing and construction of coastal embankments that came to light in the investigation undertaken are discussed below.

1. On the Designing of Embankments

The three sides, i.e., face and rear spreads and crown, of almost all the recently constructed coastal embankments have been covered with concrete, asphalt, or blocks, and it can be assumed that all embankments to be constructed in the future, with the exception of those that will be facing only minor wave action and those that are fully protected from overtopping wave action or will be facing very little of this action, will be provided with three-side coverings. A point to note in connection with the above, however, is the woeful lack of research that has been conducted on these covering materials and how these coverings should be constructed. The case of the covering thickness that has been decided can be cited as an example to illustrate this point. Despite the extensive face spread covering work with armor rocks that had been undertaken, the strong wave action led to their deterioration and subsequently to the toppling of some of the embankments to cause severe damages. From this experience, the thickness of almost all non-reinforced concrete coverings was raised to about 50 cm. In most areas where very strong wave action occurs, moreover, even precast concrete work has been undertaken with the hope of minimizing the destructive impact of the overtopping waves. The 50-cm thickness decision for the coverings, however, was not based on any mathematical computation of the thickness requirement for the concrete blocks to cope with the wave force of different strength. It was strictly an arbitrary decision based on the knowledge gained from experience that an armor of this thickness will suffice to meet all requirements. The resultant impact has been the adoption of this thickness for all armors whether or not the situation dictated the need. This development, as can be seen, could have been avoided if proper research had been undertaken long ago on the wave action stress against the covering blocks to establish a criteria to be followed in the construction and installation of spread armor with the required thickness to meet the need of the particular locality.

The same kind of situation also holds true for the embankment foundation as well. As before, experience has been the basis for the decision made on how the work should be carried out in the field; that is to say, on the type of foundation section to be constructed and even on how the new changes, such as the installation of steel, still-water, and concrete piles, must be carried out. The above is

not designed to belittle the importance of experience; it is an accepted fact that without experience, no technical progress worthy of its claim can be made. The installation of these piles is being undertaken to provide additional support to the foundation. Question has been raised, however, on the use of the still-water piles for this purpose, inasmuch as a number of cases have been discovered where the grip of this pile had broken off to cause serious damage. It is true that at the present time, the concrete piles are being used in most cases for this purpose because of their better gripping capability, but the question that remains unresolved is whether or not the grip of all of these piles could cause the soil erosion of embankments. The above as well as the proper implacement depth of these piles are some of the lingering major problems of foundation construction that must be resolved through careful research work.

In the case of embankment crowns, their growing use as roadways, even for pleasure drives and tour busses, has led to the development of not only many but serious cracks on the top surface. Since its surface use is no longer confined to few working vehicles, due care must be given to its designing and construction to accomodate the heavier traffic loads that it will be called upon to handle; that is to say, research must be undertaken to determine the proper thickness of the surface coverings, required road foundation, etc.

The general thickness of the rear spread armor has been confined to about 15-20 cm. This stemmed from the fact that as compared to the face spread armor, the rear spread armor is less exposed to the strong action of the waves. It must be remembered, however, that one of the basic requirements of an embankment is a solid and well-balanced construction that can withstand the weathering force of nature, such as sinking, soil compaction, etc., that can change its configuration. In the construction of an embankment with taller crown, it should be noted that if the aforementioned is to be the thickness limit of the rear spread armor, a serious problem can develop from the large discrepancy in thickness between the two spreads. To reduce the thickness /of the face spread armor?/, it would be necessary to construct small step/layer near the center or at the tail edge of the spread. It is believed that the minimum thickness of a non-reinforced concrete should be about 20 cm and that the most effective rear spread armor is a ferro-concrete framework or a block covering. These two can be an effective covering for a small face spread as well.

The impression gathered was that the bedding anchor section was grossly inadequate in terms of the foundation work. This flaw, it is believed, was the primary cause for the large number of exposed bedding anchors that were observed, especially for embankments with relatively tall crown. It is quite possible too that the embankment

soil erosion that had developed and washed into the rear "yuasobi" ["tidal play"] area from the embankment water flow by way of the bedding anchor location could have been caused by this flaw. As can be seen from the above, the bedding anchor must be reinforced.

The above are random thoughts on important designing requirements that came to our minds. They are not intended to serve as an analytical solution to the problems on hand. There is, however, a definite need for the undertaking of some kind of research study that can lead to the drafting of the required designing methods.

2. On the Weep/Air Holes and Air Gaps in Embankments

In most cases, the embankments and sea walls that have been constructed in our country have been built on soft and weak foundation, making it difficult to prevent their sinking. A sinking that occurs evenly will pose no problem; such, however, has not been the case for most of our embankments and sea walls. Many crooked spots can be found on these embankments and sea walls because of uneven sinking.

Broadly speaking, the embankments of our country are fairly large-sized structures that had been constructed relying on the simplest means possible. For the most part, sand available nearby or dredged sand employing pumps was used to construct the foundation. The actual construction work, moreover, was based on the minimum use of mechanical means and in many cases, very little attention was placed on the importance of embankment core solidification work. In the construction of road-beds for highways, thorough check and control of the soil moisture are first undertaken and then bedding is firmly solidified by mechanical means; in the construction of our country's embankments, however, none of these required measures is undertaken.

Unfortunately, many embankments in our country are sitting on water permeable foundations. In the investigation conducted, we observed many serious cases of embankment moisture penetration from tides, rain water, etc., and deduced that the water seepage and flow in these embankments to be fairly great. From this, it can be assumed that the water seepage problem of embankments with very fine sand is developing into a bigger and more complex problem of shifting sand. In many cases too, the embankment foundation below the face and rear spreads is made up of implaced crush rocks and pebbles, whose diameter normally ranges from 20-30 cm. It would not be wrong to assume that the gaps in-between these rocks and pebbles have been serving as the settling places for the eroded embankment earth and sand from the permeating moisture, rain water, waves, etc.

The causes cited above have led to the development of weep/air holes and air gaps in most of the embankments and sea walls and in turn, to the development of embankment cracks and breaks, aberration

of ground sites, etc., to accelerate the wastings of these structures. Information on the size of these weep holes and air gaps, their exact location, countermeasures that have been adopted against them, etc., is very scanty to say the least, but it is believed that their main location areas are beneath the coverings of the crown and the face and rear spreads. Based on the surface cracks that have occurred, it appears that the number of these holes and gaps is fairly large beneath the crown and the rear spread, but relatively small beneath the face spread. The difference in the number of surface cracks that appear for these two spreads is due to the difference in the thickness of their armors and not, it is believed, to the difference in the number of weep holes and air gaps that exist beneath these spreads. There is an urgent need to conduct thorough study and research to learn and understand the effect of the weep holes and air gaps on the wasting process of embankments. Provided below, however, are our thoughts on some of the methods and countermeasures that can be instituted to curb or reduce the development of weep holes and air gaps.

a. Adequate consolidation of embankment soil; employment of mechanical means to consolidate the embankment soil; establishment of a set procedure for embankment soil consolidation work that can be employed everywhere to ensure certain set consolidated soil for all embankments; examples: the "maki-dashi" /literally, "rolled out"/ embankment soil to be certain cm thickness; a certain ton bulldozer to run over the soil certain number of times to consolidate the soil, etc. Simple as these instructions and procedures may seem, they would be very important in facilitating the operations in this field.

b. Mixing dredged soil with some other soil for use as embankment soil rather than employing it only after pumping it out; undertake measures to ensure embankment stability by employing cement, asphalt, etc., using techniques currently employed in the construction of road pavements, levees, etc.

c. Adoption of asphalt as the crown covering; concrete coverings are too susceptible to cracks and ground site breaks; prevent or reduce as much as possible the pressure exerted against the crown surface, such as excessive traffic loads, etc.

d. Adoption of reinforced concrete framework for the rear spread and placement of blocks within this framework to make the rear spread into a flexible structure; the adoption of this method will require careful block construction work at the ground site.

e. Installation of piles to be undertaken with due care, not only to prevent the embankment soil erosion from beneath the foundation and bedding anchor but to prevent the break-off of pile grip; believe

the use of concrete pile for still-water pile will create a problem.

f. Injection of grout immediately after the discovery of a weep hole or an air gap; the detection of weep holes and air gaps is possible by means of the wasting index that has been discussed before, but is a longer time-consuming process; the detection of possible existence of a weep hole or an air gap must be followed by positive action, such as the removal of the coverings, to confirm or negate the existence.

With regard to grout injection, proper guidance including information on the equipment required, injection pressure, type of grout material (cement, mixtures, moisture content, etc.), required injection intervals, etc., must be provided to ensure proper execution of the required work.

g. Establishment of a general procedure for repairing air holes that cannot be mended by grout injection only; this procedure should include the measure instituted in the past of reconstructing the whole structure; inclusion of illustrative restoration work examples should also be considered.

Needless to say, the implementation of the measures discussed above will require budgetary allocation.

3. Maintenance and Control of Embankments and Sea Walls

The growing move for more effective utilization of the coastal area has led to the rapid growth of seaside industrial zones in our country in recent years to make the task of protecting the coastline facilities that much greater. These coastline facilities now include not only these new seaside zones and the old established residential and industrial areas with their embankments and sea walls located along the coast, but new embankments and sea walls that have been constructed by the Kocho Taisaku Jigyo [literally, High Tide Countermeasure Enterprise]. The unique feature of the maintenance and control work of a functional facility, such as a highway, mooring dike, sea route, etc., is that the failure to do so or poor work will contribute to its deterioration with every use, but this deterioration will be confined to the facility itself. In the case of the embankments and sea walls, however, the failure to undertake proper maintenance and control work will not be confined to their own deterioration alone but will have a serious impact on the facilities (homes, factories, etc.) located to the rear. In the investigation undertaken, we learned to our dismay that like the saying, "The hotness of a food is forgotten, once it passes through the throat," very little recognition was being placed on the importance of embankment and sea wall maintenance and control work. The above

is to say that the recognition of the importance of embankments and sea walls as the protective structure of the rear area, of the inadequacy of many of the existing facilities to provide the required protection, of the need for diligent maintenance and control work to preserve the existing facilities, of how much protection the existing facilities are or are not providing, of the need to replace some of the existing outdated facilities with new ones to safeguard the rear, etc., must normally await the occurrence of some disaster before it happens. From general indication, the prevailing line of thinking seems to be to wait for the occurrence of some disaster to crumble the "rokyu" [old and useless] facilities before undertaking any repair and renovation work rather than to preserve the existing facilities by means of careful and diligent maintenance and control work.

If the above thinking is true, it can be accepted as a further confirmation of the poor recognition being given by almost everyone on the importance of maintenance and control work and of the inadequate budget [sought for this work?] and of the inadequate concern for this work by the concerned organizations. At the present time, great importance is being placed on the safeguarding of our land and on the maximum utilization of our available land. In the face of this, it is strongly believed that there is a definite need for an official government statement reemphasizing the importance of maintenance and control work for embankments and sea walls.

The matter of maintenance and repair standards is one of the unresolved technical problems on hand in the maintenance and control field. That is to say, what standard should be employed for the maintenance and repair work to be undertaken. Without this standard, there would be no way to determine the type of logical work that must be carried out and the budget requirement for the work. Even after the establishment of this standard, if excessive manpower must be expended to ascertain its suitability, it will amount to no more than a confirmation of its suitability based on the intuition of the individual investigator. Normally speaking, most maintenance and repair work fall under the category of minor job and as a result, the performance of this work is undertaken by the technical personnel with experience stationed at the site. In many cases, the actual work performed is based on the intuition of these personnel. There exists the need today for a maintenance and repair manual that can be used by the inexperienced technicians to carry out this work.

The above is a brief discussion on the prevailing maintenance and control situation; it is our fondest hope that this report, coordinated with other research reports to be prepared by others in the future, will be of some service in improving the embankment and seal wall maintenance and control work of the future.

IX. Resume

Provided below are summary and conclusion of the various chapters /is a resume of the coverage provided in seven chapters?/ of this report.

Chapter II: In this chapter, the wastings of coastal embankments were examined from the standpoint of two major breakdowns: function and structure. The structural wasting was defined as the indicator pointing to the various steps of an embankment breakdown process.

Chapter III: The embankment damages that can be caused by natural calamities employing the Ise Wan typhoon as the primary example and the resulting breakdown process were examined in this chapter. The visible changes indicating wastings (wasting index) that occur to embankments in the breakdown process were also reviewed.

Chapter IV: In this chapter, the investigation methods employed in the coastal survey that was carried out were explained.

Chapter V: The on-the-spot survey results of the wasting indicators that were observed in embankments in the investigation conducted in 1970 and 1971 were reviewed in this chapter. The checklist of wasting index discussed in Chapter III served as the basis in examining the external changes that were observed (wasting index).

Chapter VI: This chapter was devoted to the study of weep/air holes and air gaps, regarded as the major causes of embankment wastings; the Aichi Prefecture Coastal Survey Report was employed as the basic reference source.

Chapter VII: This chapter discussed the method of obtaining the extent of the wasting of a structure by means of attaching values to the wasting index (visible external changes) which served as the indicator of the structural wastings.

Chapter VIII: In this chapter, discussions were undertaken (1) on matters that deserve careful attention in the designing of embankments that came to light in the investigation that was conducted, (2) on the spots and places where weep holes develop in an embankment and their countermeasures, and (3) on the maintenance and control of embankments.

X. Postscript

As briefly alluded to before, this survey and investigation revealed that (1) very little research work had been undertaken in the field of embankments, etc., in the past, (2) despite the innumerous numbers of embankment and sea wall construction that have been carried out in the past, very little data on the actual construction work undertaken have been retained and preserved, (3) the coastal preservation enterprises in our country are continuing to operate with sound financial backing, but the construction firms with adequate capital are dwindling very rapidly, (4) the absence of standardized designing and construction methods is being reflected in the different technical methods employed by the various construction firms, and (5) despite the abundance of data compiled and retained on major calamities such as the Ise Wan typhoon, very little data are being compiled on the damages suffered from the natural calamities that occur each year. The importance of compiling annual data referred in (5) above cannot be overstressed. For example, if these data were available, a comparative study of the wave actions on embankments for the various years can be undertaken to better understand the relationship between these wave actions and the development of weep holes and air gaps in the embankments. As can be seen from the above, there is an urgent need to ensure that data on construction work undertaken, damages suffered from occurring disasters, restoration work undertaken, etc., are adequately compiled and preserved in the future.

As the concluding remark for this report, we would like to express our deepest of appreciation to the port and harbor sections and the civil engineering offices and their affiliated units of Mie, Ishikawa, Toyama, Yamaguchi, and Oita prefecture for their invaluable assistance and cooperation in the preparation of this report and to the rivers, port and harbor, and agricultural land sections and their affiliated units of Aichi Prefecture and to the 4th and 5th Ports and Harbors Construction bureaus for their help and assistance given to us in the on-the-spot investigations that were carried out and for their generosity in providing us with valuable survey reports and data.